MY OWN SCIENCE PROBLEMS

HUNTER AND WHITMAN

THE MARCH OF SCIENCE

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Photo by Warren Boyer, Westport, Conn.

It is a great thing to have a hobby. These boys have formed a field club and are off on a collecting trip.

THE MARCH OF SCIENCE

MY OWN SCIENCE PROBLEMS

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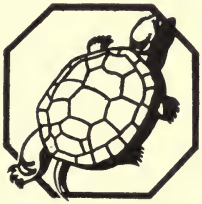

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MY OWN SCIENCE PROBLEMS. H. & W.

W. P. 6

MADE IN U.S.A.

FOREWORD TO THE TEACHER

Education in a Changing World. Great changes in educational methods and objectives have recently taken place. The growth of the junior high school is an experiment in education brought about through a desire on the part of educators to integrate the work of the elementary school with that of the high school. The growing emphasis on secondary education has forced these changes in organization. Along with this has come a new psychology of learning which emphasizes individual learning rather than group teaching. As a result of these changes in ideals and objectives, the curriculum has come into the limelight. Much recent work has been done in curriculum making, and while some has been scientifically made some is of little value. There is much evidence that the newer curricula in science are being made with objectives that are attainable. Changes in the world of today have been brought about by means of science, and some seventh grade pupils of today know more about some of the applications of science than their fathers do. There is need for interpretation of these changes in terms of the child's activities, especially in terms of his leisure-time activities. The modern science curriculum recognizes this.

If we consider what has just been said, it would seem that the underlying philosophy of the course should be based on the relationship of the environment to the child; first as an individual, and later as a growing citizen in the environment of school, community, and nation. Into such a course the materials of science should be integrated with the curricular materials of geography, history, civics,

and especially health education. At the earlier levels the ultimate outcomes from the child should be the organization of the integrated knowledges in such a way as will make for some first-hand experiences with the factors of his environment and an understanding of the part played by such factors in his life activities — a desire to know more about and to help in the improvement of his environment; while at the highest grade level of the junior high school understanding of control and usage of the factors of the environment might well be the ultimate aim. This integration, especially of positive health materials, has been made in the pages which follow.

To properly present learning elements in an integrated science curriculum at different grade levels, it is obvious that the mental age, and especially the point of view of the pupil, must be carefully considered. A terraced plan of attack must be used in which the capacities, interests, and science backgrounds of the seventh grade child must be considered as a distinct level in the development of the concepts treated in the course. Children grow much in capacity between the seventh and ninth grade levels. At the seventh grade level the teacher must use simple language. The science vocabulary should be restricted to the use of relatively simple terms. The experiments and demonstrations should be easy to understand and to perform. The teaching techniques should all be adjusted to the levels of the immature youngster of this group. At the eighth grade level, after a year of exposure to the junior high school activities, our boy or girl comes back to school in the fall with a perspective much enlarged and with a social viewpoint quite different from that held in the previous year. The instruction at this level and the quality of work will therefore be not only at a higher terrace of difficulty but should be given from quite a different social point of view.

Classroom psychology and teaching procedures have shown that while the pupil in seventh grade is an individualist, the same pupil at the eighth or ninth grade level has a quite different outlook on school life. He has become a school citizen with the responsibilities of citizenship as a part of his mental outlook. It would seem very logical therefore to make our seventh grade science center on the individual and his personal reactions to his environment by integrating his science interests, leisure-time activities, and health education material with the science concepts fundamental to an exploratory knowledge of his environment. On the other hand, as the ideals of citizenship and co-operation are developed at the eighth grade level, it would seem logical to make science concepts lead to a better understanding of such problems as are concerned with the purity of water supplies, the protection of food supplies, the control and prevention of disease in the community, and such other science topics which show the need for co-operative effort for environmental improvement on the part of school children. As the outlook of the child broadens in the third year of the junior high school, a third cycle of science activities will develop at a still higher terrace of difficulty. At this age level the child might well transfer his science interests to the wider field of the nation and the world.

The underlying theme for junior high school science should be first, at the lowest level, simple *knowledges* about the interesting and useful science in the immediate environment of the individual. In the second year *understanding* is more the goal, while in the last year *interpretation* and *application* of science are the desired outcomes. The philosophy of presentation should result in the ultimate generalization that man of all the animals is the only one who can control and artificially change his environment. As such he has dominion over the earth.

Emphasis in science teaching is coming, more and more, to be placed on method, on problem solving, and on the use of science facts in the solution of such simple problems as are within the pupils' comprehension. Although generalizations and fundamental concepts are teachers' goals, they are not so evident to the pupils. Therefore science courses must lead the child to see and later to understand the reasons for many simple demonstrations and experiments to the end that these understandings will lead to the goal of forming correct generalizations. Mature generalizations are not the immediate goal; it is the *forming* of these generalizations through science experiences gained through the usage of science materials that makes for the best teaching of science. Moreover, these generalizations should be so mastered that they may be used by the student in explaining new science experiences with which he is continually coming in contact. Thus his knowledge is made usable and applicable. Science teaching will never function with the mere *learning* of *generalizations;* they must be used and applied intelligently in other science situations.

Our coming social group is bound to have more leisure time, as the economic conditions in the future will doubtless make for a substantially shorter working day and more and more time for avocations. The place of science in the junior high school points primarily to adjustment of the pupil to his environment so that he may best use these leisure hours. Science can do much for him in awakening interests and making hobbies worth while. Hobbies are important, both for young people and for older ones: collecting, fishing, hiking, keeping pets, gardening, anything that makes for intelligent interpretation and use of the environment.

This series of texts has been prepared keeping in mind not only the recommendations of the most scientific

workers in the junior high school curriculum, but also such experimental work as is available. Interest studies, controlled classroom experiments, research studies in the use of science material, the pooled experiences of teachers, the work of the Science Committee of the National Education Association, and the outstanding recommendations of the Thirty-first Yearbook have all been used in an attempt to make this series educationally as well as scientifically sound.

Certain unique features in the series stand out. In the first place the texts are written from the pupil viewpoint and great care has been taken to present the material so that it may fit the age level of the pupil. Concepts grow and what may be meaningful to the ninth grade pupil could not be understood clearly by the pupil in the seventh grade, therefore a cyclic plan of treatment is used which is believed to be psychologically sound. Young people are interested in the science of the world around them, not in blocks of a given part of science. As Cox so well says: "A child of the junior high school age lives in a world of things, forces, phenomena, and people. He does not live in a plant and animal world in the seventh year, and in a health world his eighth year, and a physical science world his ninth year." [1]

Emphasis throughout the series is placed on *thinking* rather than on the *reproduction* of *facts*. Factual material is necessary. In this series of texts the factual material is used in a purposeful way to the end that simple science problems may be solved. These problems are fitted to the age level of the pupil so that even in the seventh grade he may become habituated in the methods used by the scientist. A conscious effort has been made to give the pupils reasons why the method of the scientist is useful

[1] Cox, P. W. L., *The Junior High School Curriculum*, Scribner, 1929. By permission of the publishers.

in daily life to the end that a transfer of training may take place.

The psychology of the unit with its social aspect is a force which makes for pupil interest and learning. The Morrison techniques, with modifications which have been found desirable, are used throughout the series. Emphasis has been placed upon learning devices, and a conscious attempt is made to show the pupil reasons for doing because of the desirable outcomes in transfer of training.

Cuts and diagrams are presented as learning devices. The Chinese saying, "A picture is worth 10,000 words," showed a deep pedagogical insight. In this text many pictures are used and thought questions are so worded that the child will use the text as well as the picture in trying to answer the questions in the legends. While the value of the child's recognition of the big ideas and generalizations in science is seen, the greater importance of properly arriving at these generalizations has been stressed in this series. Numerous devices are used to this end: The Review Summary outline, with its suggestions to the pupil for the proper method of preparing for the recitation; the practice in problem solving by means of the presentation of the textual material in problematic form; the various types of self-testing exercises and the many thought questions at the ends of the units are examples of such aids. In the so-called "Story Tests" more factual material than appears in the text is often given, to the end that teacher and pupil discussion will be stimulated and reading encouraged. In addition constant use is made of the motivation which comes through desirable activities such as those obtained by science clubs and excursions. Leisure-time activities are also used as a means of stressing interest in learning science.

ACKNOWLEDGMENTS

It would be impossible to write a series of science textbooks for the Junior High School without mentioning the many pioneers in curriculum making such as Barber, Briggs, Carpenter, Charters, Cureton, Cox, Curtis, Frank, Harap, Pieper, Powers, and many others, including the committee who were responsible for the curriculum findings in the Twenty-sixth and the Thirty-first Yearbooks of the National Society for the Study of Education. The establishment of courses in science at this age level is still in the experimental stage. But successful courses must be based on the findings of interest studies as well as successful practice of teachers who are practical and pragmatic in their philosophy of teaching.

The writers of this text have frankly belonged to this latter school, and the pages which follow are the results of practical work in the classroom, together with the acceptance of such findings in experimental teaching as best illustrate these objectives. It would be impossible to name all the teachers who have given help and inspiration to the writers, but the mention of the following must be made because of the personal contacts involved: Dr. Edna Bailey and Dr. Anita Layton of the University of California; Dr. Otis T. Caldwell of Columbia University; Professor W. L. Eikenberry, State Teachers College, Trenton, New Jersey; Miss Winifred Perry, Roosevelt Junior High School, San Diego, California; Dr. Frank M. Wheat, Head Department of Biology, George Washington High School, New York City; and Professor Herbert E. Walter, Department of Zoölogy, Brown University, Providence, Rhode Island. From each of the above, the writers have had help and inspiration.

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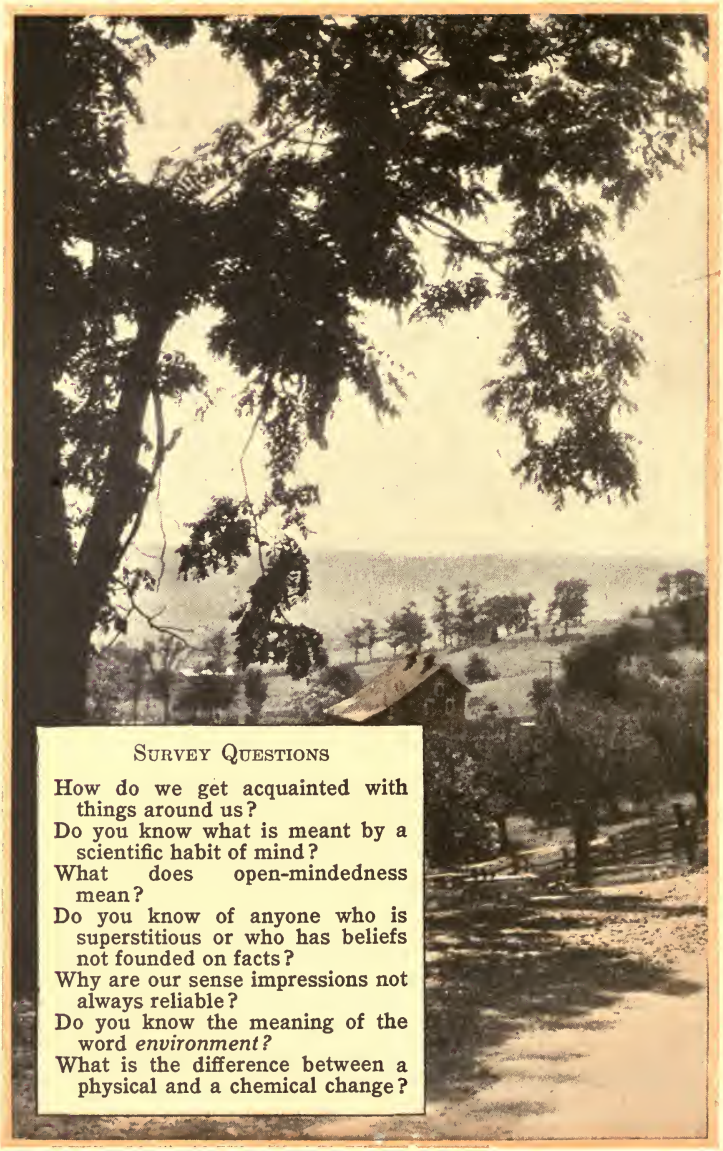


Survey Questions

How do we get acquainted with things around us?
Do you know what is meant by a scientific habit of mind?
What does open-mindedness mean?
Do you know of anyone who is superstitious or who has beliefs not founded on facts?
Why are our sense impressions not always reliable?
Do you know the meaning of the word *environment?*
What is the difference between a physical and a chemical change?

Armstrong Roberts

UNIT I

GETTING ACQUAINTED WITH THINGS

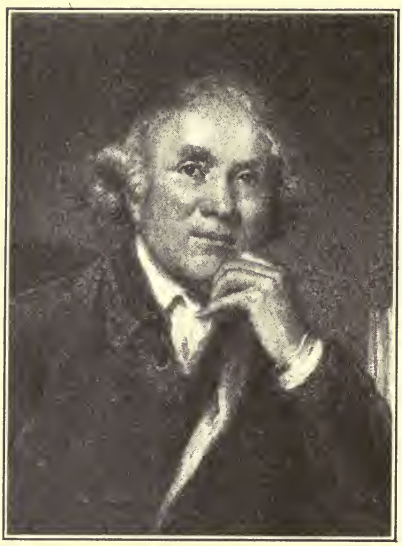
PREVIEW

Have you ever climbed a high hill and looked off over the countryside? What a lot of things you could see — trees and open fields, brooks and lakes, hills and valleys — with perhaps homes scattered here and there through the landscape. If you looked more carefully, you could see many other smaller things: the leaves on the trees, birds flying, insects buzzing through the air, stones on the ground. You could count hundreds of different things that you could see from that one hill.

But how were you able to know that all these different things existed. You could see them, touch them, perceive that some things had a pleasing odor and that some tasted good or bad. It was different from seeing a picture. You could tell these different things existed and were real because of your ability to see, touch, smell, or taste them — in other words, you became acquainted with them through your senses.

A good many years ago before science was used very much in people's thinking, it was the custom for some philosopher to write a book, and then his pupils and all who believed with him would follow exactly what was said in the book without using their senses for themselves. It is said that John Hunter, a famous Scottish physician and surgeon, was once present at a meeting of scientists when they were discussing the structure of birds. The different men present quoted from various books the sayings

of the old philosophers, Aristotle,[1] Galen,[2] and Hippocrates,[3] concerning the structure of the bird. One philosopher said one thing and another something else. They did not seem to be in agreement. Naturally this set up a great discussion in the group, for some believed what one philosopher said and others took sides with another statement. But John Hunter got a bird, killed it, and cut it open and showed the position of the various organs to the group. Naturally they had nothing to say because John Hunter had used the method of the scientist; he had used his senses in obtaining evidence; something real that could be seen and touched, not just read about.



Culver Service

John Hunter. After reading this unit decide if he showed the method of the scientist in his actions.

Have you ever tried to discover all the different forces and things that go to make up your surroundings? There is first of all the air, which seems to be necessary for all living things. Then there is water and fire and sunlight, all essential to our existence. The soil or the earth's surface with its living inhabitants might be considered as another part or factor of our surroundings. Scientists also consider such forces as electricity and radio activity,

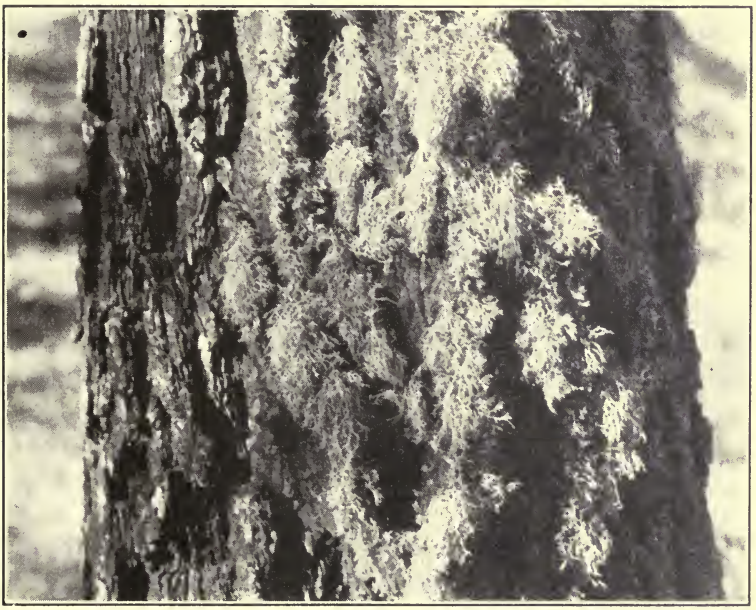
[1] Aristotle (ăr′ĭs-tŏt′l). A Greek philosopher who lived 384–322 B.C.
[2] Galen (gā′lĕn). A physician of ancient Greece.
[3] Hippocrates (hĭ-pŏk′*rə*-tēz). A Greek physician born about 400 B.C.

forces which act upon living things. All of these forces and things we collectively call our environment, and each one by itself is a factor of the environment.

This unit is intended, first of all, to show us the way that we get acquainted with our surroundings and how we may use the method of the scientist in learning something about this wonderful world that surrounds us, what our surroundings are composed of; and, finally, how we as living creatures use this environment in which we are placed.

PROBLEM I. HOW DO WE GET ACQUAINTED WITH THINGS?

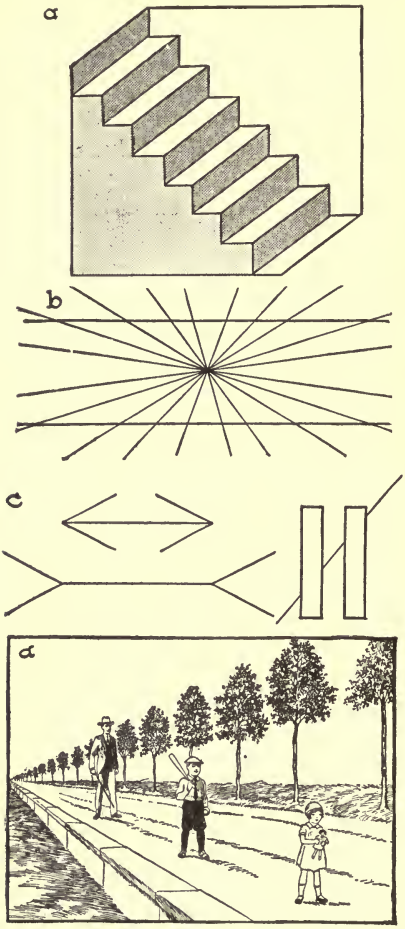
Indians Were Keen Observers. Those of you who have read *The Last of the Mohicans* remember Uncas,



Wright Pierce

The next time you are in the forest look on one side of the tree trunk for a green mosslike growth. This is not moss, but algae or lichens, low forms of plant life.

the Indian brave, who was able to find his way through the trackless forest because he observed and remembered all the things in the forest that might serve as guide posts. The green growth on the trunks of the trees, a mark on a rock or tree trunk, a broken twig, or unusual sound, each had its message to the keen-sensed Indian. We think this was very wonderful, but a boy or girl who uses his senses carefully and makes observations that are accurate will soon find that these signs, which might be unnoticed by the poor observer, have a real story to tell.



Turn book so that top of cut *a* is at bottom. Slowly turn book while watching the stairs. Result? Are the two horizontal lines in *b* parallel? Do the two horizontal lines in *c* appear the same length? Measure them. Is the line cut diagonally by the two oblong blocks a straight line? Which of the three figures in *d* appears tallest? Measure.

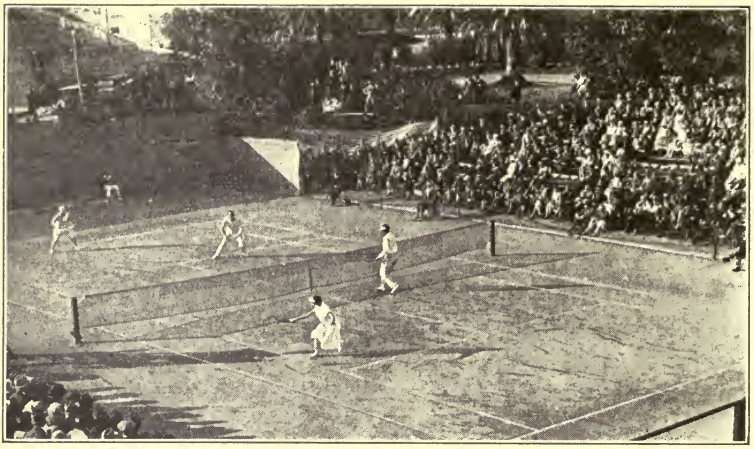
More Than Observation Necessary. But observation alone will not take us far. The Indian saw accurately but he also said to himself that this green growth on a tree means "north side," and that broken twig means "some one has passed this way." So it is with any one who

studies science. His observations may be good, but, unless he relates his observations to something that he wants to know, he will not get very far with his study.

Sense Impressions Are Not Always Reliable. If you look carefully at the picture on page 4, you are quite sure that the man in the picture is taller than the little girl shown in the foreground. But if you draw lines touching the tops of the heads of the three figures and the bottoms of the feet of the three, you will be surprised at what you find. Try it and see for yourself. This shows us that sense impressions, even when carefully made, cannot always be relied upon.

We Need to Know Where We Are Going. Uncas, in his wanderings through the forest, made his observations with some object in mind. If he was stalking deer, it was signs of deer that he looked for. If going through a hostile country, it was signs of enemy that he sought. So it is with any one who studies science — or indeed any school subject. He must know where he is going and what he is after. Our observations must be directed toward one goal and we must know just what this goal is. In science we call it a problem and we say we are trying to solve a problem. This interesting old world in which we live has so many interesting problems for us to solve — secrets which can only be discovered when the observations we make are directed to a goal in which we are interested. Remember this in your science work and it will always seem worth while.

Life Is a Continual Solving of Problems. But, you say, this isn't true. We are not solving problems when we are at play. Think a moment — tag, or swimming, or football. In tag, you must dodge; but does quick dodging just happen — or do we *learn* to dodge skillfully? Did we ever have to learn to swim? Ask the football player about the successful plays that win the game.



Wide World

Tennis tactics require problem solving. The couple at the net have been successful in solving theirs.

You will find that most things in life that are worth while involve thinking, and thinking ought to mean problem solving.

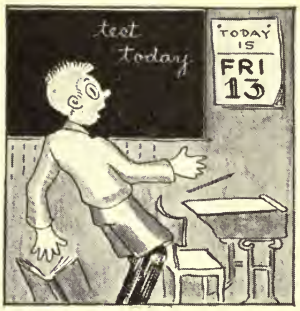
The Scientist Has a Way of Looking at His Problem. One of the most characteristic things about a scientist is that he is open-minded. He never makes his mind up until the evidence is all in. Some people say, "I make up my mind and keep it made up." Such people are not open-minded. They are not willing to accept new evidence that might oppose what they think. The scientist, on the other hand, is always looking for new evidence. He is always open-minded. He may have a theory, but he will give it up if his experiments give him answers which do not agree with it. Charles Darwin is said to have experimented with certain animals in hopes that they would do something that would prove a theory he then held, but when they didn't, he would say in an admiring way, "The perverse little beggars, they will do it their way."

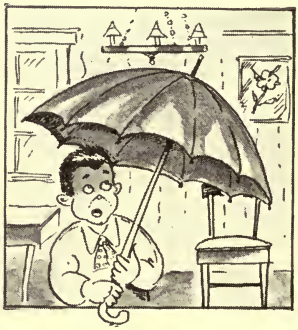
How Do We Form Habits? A habit is said to be an act or attitude which is learned through practice. Habits are of many kinds. Some are concerned with our way of looking at life. We may be habitually happy or grouchy, kind or cross, scatter-brained or able to concentrate, depending on the habits we form when young.

A good many rules have been made to aid us in habit formation. Here are some worth remembering:

1. Know what habits you want to form and then act on every opportunity.
2. Make a strong start. No half-hearted effort was ever successful in forming new habits.
3. Allow no exceptions. Habits are only established by keeping right at it. One misstep means we start all over again.
4. In place of bad habits establish good ones. Habits always have opposites.
5. Use every effort of will. Never say, "I can't," and you will one day wake up to the fact that you have established your new habit. Straight thinking is really a habit of mind. If we can only get the habit of making our decisions on evidence which is real and not on hearsay, we would be saved much trouble in later life.

The Scientist's Method of Thinking in Everyday Life. You can see from what has just been said that the scientist looks at things fairly and squarely, and that he always tries to find out the truth by means of the evidence obtained from asking questions of nature. He is not satisfied with anything but the truth. How much it would mean to each one of us in daily life if we could take the scientist's method of thinking and refuse to be satisfied with propaganda or newspaper stories which tell half truths. We would be less likely to believe many of the superstitions which many people have faith in. What evidence have you that bad luck is associated with number 13? What





How many of these beliefs do you hold? Can you find any reason for holding these beliefs? Do you believe that the ground hog can foretell the weather? Or that you will have good luck if you see the new moon over your left shoulder with money in your pocket? If you do you are not scientific in your attitudes.

evidence have you that breaking a mirror carries bad luck with it, or that a black cat crossing your path means bad luck, or that walking under a ladder will be harmful? A moment's thought will show you that there is no evidence for the truth of these superstitions. Every boy or girl who studies science should determine that he will carry over into his daily life this way of looking at science problems. You may be sure it will mean much to your peace of mind now as well as make you a more intelligent and thoughtful citizen.

Use of Workbooks. Every pupil should keep a notebook in which are recorded observations and facts noticed and learned demonstrations, statements made by the teacher, and notes from supplementary readings. Outline drawings of the apparatus used in some of the experiments, and of the machines, animals, or plants, which he wishes to remember, should be in this book which we will call a *workbook*. When the work of each unit is organized for review, an outline form of the unit should be recorded, as well as brief but clear reports of special projects, experiments, labeled diagrams, and figures which are necessary for a clear understanding of the various problems of the unit. Finally, the workbook may contain a collection of clippings, pictures, and photographs, related to the various topics. Your workbook will be something that you can keep after your course is finished. It will not only be a memento of a worth-while bit of individual work, but it also will serve as a reference book to be used if you go on with the subject of science.

How to Use the Self-Testing Exercise. In the pages that follow we shall find at the end of each problem a self-testing exercise; the object of this exercise is to help you master the problem which it closes. To make the best use of this exercise, you should place the numbers of the blank spaces in columns on a sheet of paper. Then read-

ing the self-testing exercise carefully, try to see how many of the blanks you can fill in. After you have done all you can, go to your teacher and see how many words you have missed. Then go back to your text and your notes in your workbook and study again the part you missed. After a short time try the test again and see if you now can fill in all the blanks. Do not give up until you can fill in every blank correctly without looking at your text. If you can do this after an interval of say half an hour after you looked at the book, you should have mastered the facts contained in the problem.

How to Use the Story Test. Next try the story test. This may contain some misstatements and is supposed to help you get some of the big ideas or generalizations contained in the problem. Use this test as you did the self-testing exercise, checking up with your teacher to see where you are wrong. Then go back to the text and see what it is that you did not understand. These tests should help you greatly if you use them in the manner just suggested.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below, and arrange them in proper numerical order. A word may be used more than once.

problem	impressions	method	characteristic
problems	determination	play	concentrate
open	work	observer	goal
closed	learn	experiment	success
thought	study	judgment	weighing
scientific	signs	will	solving
propaganda	attacks	constantly	evidence
sane	reliable	unnoticed	sense

Perhaps the Indian could not repeat many science principles, but he learned to become a keen (1)____. His watchful eye noted many (2)____ which had a meaning to him, but which might pass (3)____ by you or me. One must (4)____ to recognize illusions

because not all sense (5)____ are (6)____. Throughout life one (7)____ has (8)____ to solve, not only in his (9)____ but also in his (10)____. In science one learns a (11)____ of solving (12)____. The scientist (13)____ problems with an (14)____ mind. It needs strong (15)____ power and (16)____ to change a habit. The habit of (17)____ (18)____ before forming a conclusion is (19)____ of the (20)____ method.

STORY TEST

GEORGE WRITES ON THE METHOD OF THE SCIENTIST

Read carefully and critically. List all the errors and suggest corrections.

I want to be a scientist when I grow up so I have decided to form the habit of thinking like a scientist. First of all, a scientist always makes his mind up as to whether a thing is so or not and never changes it. That is the way to successfully solve problems. You must try to see the end or reason for doing certain things. It is not wise to have an open mind and listen to everybody's views. It is much better to have a mind of your own and not allow your ideas to be changed by anyone. The scientist may find out the truth by means of evidence, but the easiest way to be sure to have the right evidence is to ask someone rather than to depend upon your own experiments or experience. If the Indians had only made some practical use of their ability to observe accurately, we might credit them with using reason. The scientist always tries experiments and asks questions of nature to see if he is right in his problem. I would never study books in science for you cannot learn anything from books. I would always make experiments, and if they came out the way I thought they ought to come out, then I would believe them. In other words, a scientist always believes his senses.

PROBLEM II. WHAT IS OUR ENVIRONMENT AND HOW DO WE USE IT?

What Are the Factors of Our Environment? Just what do living things need in order to live? Growing boys and girls use air in breathing, drink water, eat food, are comfortable at a certain temperature, need light, and also need something to live on, the earth. With our present

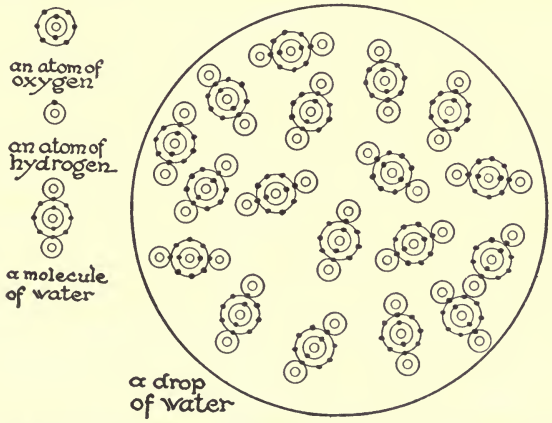
Photo by U. S. Forest Service *Orient and Occident Photo* *N. Y. Times and St. Louis Post Dispatch*

What factors of the environment are alike in these pictures? Which are different?

knowledge it would be difficult to prove that plants and animals use in one way or another all of these forces and things which surround them, but such is the case. The bird in the air, the fish in the water, the tree in the ground — all living things — use some part of the air, water, a favorable temperature, light, and some kind of supporting substance, as the soil, in order to live. Hence we call these the *factors* or parts of the environment.

Living things depend upon the factors of the environment. We could easily prove that these factors of the environment were necessary for life by simple experiments. A fish will die out of water, and no animal or plant will live long without this important substance. If the plant or animal were placed in a jar from which it could exhaust the air, we would find that it would die as soon as the air supply was cut off. Light is essential to most living things, for all green plants and most animals prefer light. Some require much heat; others, like the polar bear, prefer a cold climate. Some plants can exist in temperature which would mean death to others. And all living things find some support necessary for their bodies, usually either water or soil. We know that living things need and use factors of their environment, but *how* they use these factors is much more difficult to understand.

The Nature of Matter. The person who considers only plants or animals in relation to their environment might be satisfied to stop with the factors mentioned above. But the scientist wants to know more about the environment. He is not content to know what things do; he wants to know how they are made. He will tell you that all these factors of the environment as well as the living things found in these are made up of something he calls *matter*. Matter, according to the scientist of yesterday, was anything that had weight or filled space. But the scientist in our changing world is not content to stop with this definition. He says experiments show him that matter behaves as if it were made up of tiny particles separated by spaces. He can take a hollow iron ball filled with water, which looks quite solid to the human eye, and by subjecting it to great pressure, can squeeze water right through it. This, he says, could not be done unless the iron were built of particles which are not continuous but are separated from each other by spaces. The scientist calls these particles *molecules*. But he does not stop there. He says that the molecules can be broken



Read the paragraph on "The Nature of Matter" carefully. The electrons are represented by dots and the protons by small circles. Can you explain this diagram?

down into still smaller particles called *atoms* and those into still tinier bits of matter which he calls *electrons* and *protons*. We see a good deal in the papers and magazines about these tiny electrons, which the physicist says are a form of electrical energy, but nobody has ever seen one. Our present idea of the nature of matter is only a theory, but so sure is the scientist of his experiments that the modern world has come to accept this theory as a basis on which we build all our knowledge of matter.

Elements and Compounds. In order to understand a little about what goes on in the world we must know something about how changes in matter are brought about. To do this we can make a little excursion into the field of chemistry. The chemist says that all matter is compounded of simple substances called *elements*. The entire universe is made up of these substances, of which there are about 90, and he says that these elements can combine to form *compounds* which are so numerous that everything, living or dead, is made up of these substances. Some elements we know: oxygen, for example, is the gas we need if we are to breathe. You have perhaps seen the experiment made in which a red powder, red oxide of mercury, is heated in a test tube. As the substance gets hot, we see the red substance change to glistening drops of mercury such as you see in the bulb of a thermometer. If you insert a glowing match into the test tube, it bursts into flame, showing the presence there of a gas which supports the flame. This is oxygen, a gas which helps things to burn. This experiment shows that we can break down a compound into its original elements, which in this case are the elements oxygen and mercury.

Energy. A lighted match gives out heat and light. Exploding gasoline can move an automobile. A thrown stone may break a window. When matter is in a condition of motion it can exert a force it does not have when

it is at rest. When wood burns it produces factors of our environment that did not exist before. These new factors, such as light, heat, chemical action, electricity, and mechanical action, are forms of *energy*. Matter without energy would make a very different world from ours. Energy is just as useful as matter and the two always are to be found together and they are present in everything in the universe as far as we can tell.

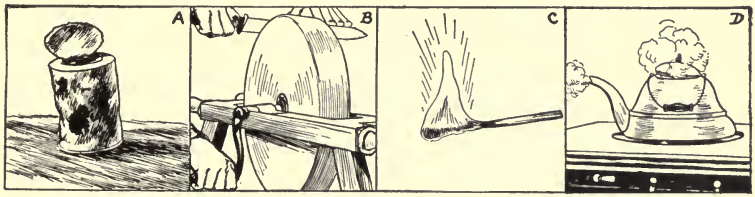
What Is a Chemical Change? When we burn a strip of magnesium metal, we get a bright flame, and there is left a white brittle compound called magnesium oxide. Here we have combined oxygen from the air with the magnesium and have an example of a chemical change called oxidation.

When magnesium is burned, oxygen combines with it and a single new product results. The change is *chemical*. The chemist expresses this change as follows:

2 atoms of Magnesium	+	2 atoms of Oxygen	=	2 molecules of Magnesium oxide
2 Mg.	+	O_2	=	2 MgO

When iron rusts, we have a similar chemical change taking place: oxygen of the air unites with the iron, forming iron oxide. Such changes are continually taking place in nature. We shall see later that life itself depends upon this process of oxidation.

Physical Changes. When your knife gets dull and you have to sharpen it, you do not change the composition



Which of these changes are chemical and which physical? How many similar changes can you list for your workbook?

of the blade. Some of the molecules are scraped off by mechanical means, but they are still iron molecules. Such a change is *physical*. Physical changes are illustrated by writing on paper, boiling water, bending a wire, grinding corn, and plowing soil. The composition of the molecules is not changed by a physical change, but is changed by a chemical change.

We Use the Factors of the Environment. What do these facts about chemistry and physics have to do with us? What is the meaning of chemical and physical changes in the world about us? All we need to know now is that such changes are continually going on and as a result of such chemical and physical changes we are able to use our environment. Take, for example, the burning of coal. Energy or power to do work is locked up in the coal. It is unused until the coal is burned, then heat is released and this heat may make water boil, turn the wheels of a locomotive, draw cars and passengers, and cook our food. How does this energy get out? It gets out simply because the elements, hydrogen and carbon, in the coal unite chemically with the oxygen of the air, forming new substances and releasing the heat which may be transformed by machines into work. Chemical changes of this sort are constantly going on in nature; rocks are crumbling and breaking down into soil; the soil itself is uniting with oxygen and breaking into still finer pieces; foods in the bodies of plants and animals are being combined with oxygen or oxidized to release energy.

Life Is a Series of Physical and Chemical Changes. And physical changes are going on as well. Wind and water break down and wear away solid rocks, and water turns wheels to transform their energy into power, perhaps in the form of electricity. Ice is formed from water. We may see it in the form of a glacier moving slowly down a

mountain side or it may fall from the clouds as snow or hail.

In our own bodies hundreds of chemical and physical changes are taking place every minute as the human machine changes its position in walking, running, swimming, driving, and even sitting or resting. Our muscles are always at work, — contracting, relaxing, — thus showing physical changes. And inside the body complicated chemical changes are taking place : food is being digested ; we breathe and the oxygen of the air unites with the digested foods as we do work. Work done by the muscles involves still more chemical changes. All life as seen from the standpoint of the chemist and physicist is a series of chemical and physical changes. And in the complex environment of today more and new physical and chemical changes are found as man makes use of new and different helps in his everyday life.

Man's Environment Much More Complex Than It Used to Be. If we were to compare the life of Uncas, the

Compare the living conditions of the Indian with those in a modern city. In what ways do they differ? In what ways are they alike?

Indian, with the life of the average boy or girl of today, we would find a vast difference in the environment. The Indian lived simply on natural foods; if he had a fire, it was rarely used for anything but cooking; his shelter was primitive and his methods of transportation and communication even more so. Contrast his life with that of the boy or girl who reads these lines — paved streets; rail, motor, and air transportation; the telegraph, telephone, and radio; the elaborate homes and great apartment houses of the cities; the systems of water supply, lighting, and heating that are now a part of our lives would seem very strange to the Indian who occupied this land not so many years ago. Man has greatly changed his original environment and made this world a pretty complicated place in which to live. This book will help us to understand better how to enjoy and control our environment.

SELF-TESTING EXERCISE

Select from the following list the words that best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

chemical	continuous	particles	electrons
compound	physical	elements	factors
molecules	largest	oxide	magnesium
atoms	electricity	protons	oxygen
masses	smallest	pressure	separated
united	microscope	rust	inanimate
composition	environment	electron	weight

Water, air, and light are three of a group of things which are called (1)____ of the (2)____. Matter which appears (3)____ is really made up of minute (4)____ called (5)____ which are (6)____ by spaces. These (7)____ are made up of atoms, and according to the latest theories, all matter is composed of still smaller electrically charged bodies called (8)____ and (9)____. When the element magnesium is burnt, it combines with the element (10)____ and produces the (11)____ magnesium (12)____. Chemical changes

always involve a change in the (13)____ of the molecules; all other changes are (14)____. Boiling water is a (15)____ change, and burning a match illustrates a (16)____ change.

STORY TEST

Mary Tells How We Use the Environment

Read carefully and critically. List all the errors and suggest corrections.

The environment is everything around us. It may be natural or artificial. The factors of the artificial environment are air, light, water, temperature, and something to rest on, or grow from, such as rocks, soil, or the ocean. I have a little garden where I put seeds into the dry earth and the warm sunshine makes the plants develop and grow. It certainly is like magic. Air, water, food, and soil are factors of our environment, but heat, light, and gravity, while we make use of them on occasion, are not really factors of the environment because they are not substances. They are mere creations of the imagination. Fish can live without light. We do not need to burn coal to get heat, we can move south where we shall not need it, and gravity is harmful as well as beneficial. It is gravity that makes the disastrous land-slides and causes us to fall down.

THE REVIEW SUMMARY

You have now come to the point where you want to find out how much you really understand of the unit you have just studied. To do this best you should be prepared to get up before the other members of your class and, with a brief outline of the unit in your hand, explain to the class any or all of the problems, as your teacher may wish. Perhaps you will be asked to make a recitation on only a single brief topic, or you may be asked to discuss an entire problem. In any event, you will want to prepare an outline from which to recite so that you will not miss any important parts of the unit. In this first unit a suggested outline will be given; but in the later units you must make your own outline. If you wish to change them, you may do so. These outlines should be based upon what you have read, learned, and done, and upon the big

ideas or generalizations that are found in each unit. In this first unit, for example, those placed below are examples. Perhaps you will want to add or subtract from this list.

1. The scientist observes carefully and uses his observations to form conclusions.
2. The scientist is open-minded. He will base his conclusions only on evidence.
3. The scientist's way of thinking becomes habitual if practiced in daily life.
4. People who are influenced by superstitions are not using the method of the scientist.
5. The environment is everything that surrounds us.
6. Living and lifeless things are made up of matter.
7. Matter is not continuous but is made up of very small particles.
8. All we know about matter has been learned through the method of the scientist.

Your outline should be based on all the facts that you have learned plus the generalizations formed as the result of applying these facts in your daily thinking. If you follow this method, it will help you in preparing your outline because you will thus focus on the most important things in the unit. A suggested outline follows. Perhaps you can improve upon it.

How we get acquainted with things:
- By sense impressions
- These not always reliable

The method of the scientist is:
- Problem solving
- Open-mindedness necessary

Habits:
- How formed
- Habits necessary for scientist

What is environment
What are its factors
What is matter:
- Theories of composition
  - molecule
  - atom
  - electron — proton
- Chemical and physical changes:
  - in matter
  - in living things

Man has changed his environment by applying scientific facts.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT, *the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place the numbers of all statements you believe to be incorrect. Your grade = right answers* × 2.

I. **We get first-hand knowledge of our environment through:** (1) our minds; (2) our senses; (3) our sense organs; (4) the nerves which cause movement of muscles; (5) talking with our friends.

II. **The factors of the environment are:** (6) water; (7) clouds; (8) the things inside of a house; (9) air; (10) degrees of heat.

III. **The method of the scientist:** (11) uses the experiment; (12) means having a decided point of view and holding to it; (13) uses the senses; (14) is essentially problem solving; (15) uses the facts in order to draw conclusions from them.

IV. **Green plants use from their environment:** (16) water; (17) dissolved minerals; (18) sunlight; (19) insects; (20) milk.

V. **The following things are made of matter:** (21) water; (22) a feather; (23) a thought; (24) a person's brain; (25) light.

VI. **There is energy used when:** (26) we chew our food; (27) a balloon rises; (28) a falling balloon hits the ground; (29) water freezes; (30) lightning strikes a tree.

VII. **Animals use the following from their environment:** (31) plants; (32) nitrogen of the air; (33) water; (34) oxygen from the air; (35) sound.

VIII. **The following are chemical changes:** (36) cooking meat; (37) soldering two pieces of tin together; (38) freezing ice cream; (39) sharpening a knife on a stone; (40) digesting food.

IX. **An example of a physical change is:** (41) throwing a stone; (42) lighting a fire; (43) putting out a fire; (44) dissolving salt in water; (45) writing these words.

X. **The use of the scientific method helps** (46) to dispel superstitions; (47) to tell which horse will win every time; (48) one to think straight; (49) to make discoveries; (50) to apply facts in useful inventions.

THOUGHT QUESTIONS

1. What are two things which everything contains and neither of which would be of any use without the other?

2. Can you usually tell by observation whether a change in body is a physical or chemical change? Explain.

3. Which of the following actions are chemical changes and which are physical changes? Why?

a. Melting of lead
b. Burning of wood
c. Making a pencil mark on paper
d. Boiling of water
e. Rusting of iron
f. Souring of milk

4. How can you train yourself in observation?

REPORTS ON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. My home environment (in one of the following localities: a farm, a city, a mining town).
3. Compare the environments of the American Indian and the early cliff dwellers.
4. What superstitions do your friends have that actually influence their behavior in any degree?
5. How some important elements are obtained from compounds.

SCIENCE RECREATION

1. **Chemical and Physical Changes.** Making a smoked sun glass with which one may safely look at the sun to view sun spots (through a telescope) or at an eclipse.

When a candle is lighted, notice the melting of the wax — some wax runs down the sides and hardens. Bring the glass down over the flame. Keep it moving so that the glass will not break. Try to get an even deposit of black carbon over the surface of the glass. The molecules of the wax of the candle contain hydrogen and carbon. When the flame is cooled, the hydrogen burns, but all the carbon does not burn. This unburned carbon is deposited over the surface of the glass. List the kinds of changes — melting wax, solidifying wax, burning wax, separation of carbon, deposit of carbon on the glass.

2. **Are You Superstitious?** Make a list of superstitions that have to do with the number 13, broken mirrors, salt, black cats, ladders, posts, moon, umbrellas, warts, etc. Tell how you could subject some one of these superstitions to a scientific test to see if they have any foundation of truth.

3. **How Is Your Second Sight?** Place 10 pairs of objects on a table. They may be of the following nature: a pair of scissors

cutting cloth, a knife cutting an apple, thread in a needle, pencil on a pad of paper, pen in an ink bottle, stamp and an envelope, cup and saucer, cracker and cheese, soap and water, baseball and player's glove. If you have a party of 12, invite six at a time into the room to look the things over on the table. After two minutes (perhaps one minute) send them back. Give each a pencil and paper — warn them not to talk — and have them write out a list of the pairs of objects seen. Have each check their answers when you read the correct list. Have a simple prize for the winner. To make the game more difficult, separate the paired articles on the table so that no two things to be paired will be together, but ask them to make their list of pairs of things which commonly are used together.

SCIENCE CLUB ACTIVITIES

1. A field trip to discover as many kinds of environment as possible.
2. To make a list of superstitions of your locality and find out how many members of the science classes are influenced by any of them.
3. Visit a factory or a hospital to see some of the recent results of science in these places.
4. PHYSICAL VERSUS CHEMICAL

Divide the club into two teams. One team will bring to the meeting a list of important common physical changes. The other team will bring in a list of important common chemical changes. Have the two teams present in turn a change and argue why it is important. Give a point for each important change and see which team runs up the largest score. Choose some disinterested party to act as umpire to decide questionable points.

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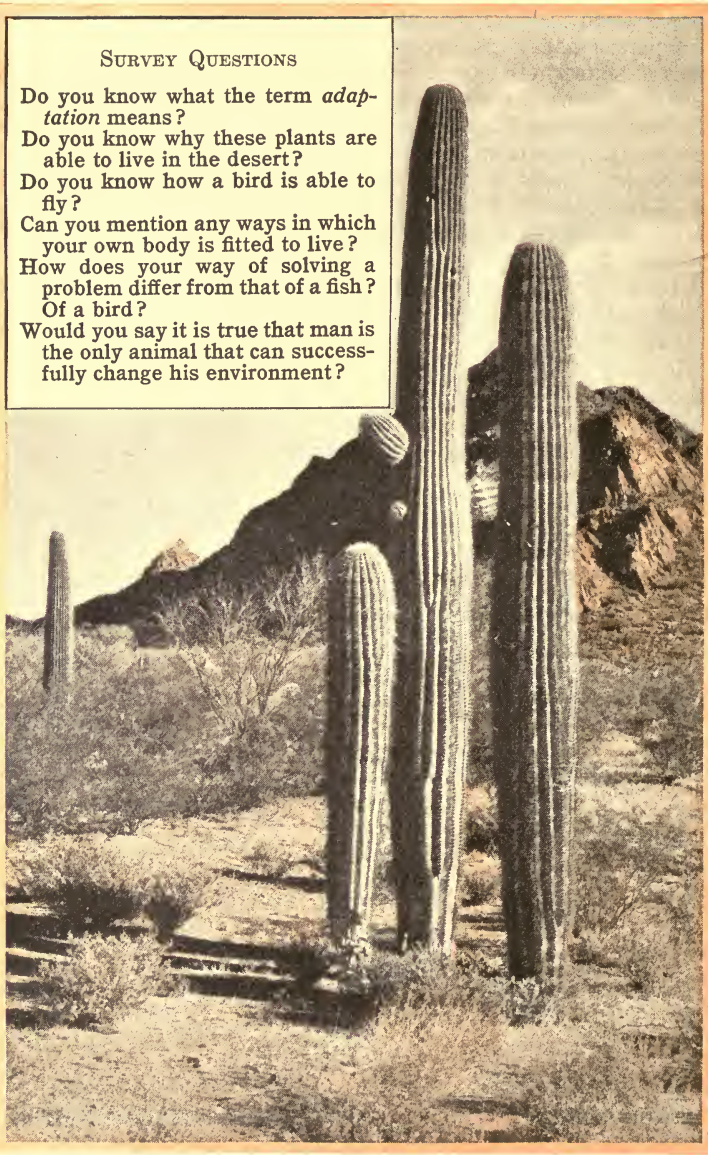
Survey Questions

Do you know what the term *adaptation* means?
Do you know why these plants are able to live in the desert?
Do you know how a bird is able to fly?
Can you mention any ways in which your own body is fitted to live?
How does your way of solving a problem differ from that of a fish? Of a bird?
Would you say it is true that man is the only animal that can successfully change his environment?



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UNIT II

LIFE DEPENDS ON ADAPTATIONS

PREVIEW

Every boy or girl who reads these lines has at one time or another kept a pet. Perhaps it was a dog or cat or a bird. Some of us enjoy watching goldfish or the brightly colored tropical fish that are so much seen in the home aquariums today. Some boys keep turtles and find them very interesting pets. We might take a census of animal pets kept by pupils taking science and add many new animals to the list.

Some of us prefer gardening or the keeping of plants at home. Hyacinths, jonquils, or other bulbs make a fine showing in the spring, while geraniums are always pretty and easy to grow. We may even have collections of strange spiny-covered cactus plants or a "burl" from a giant redwood. But no matter whether you had plants or animals to care for, you must have noticed that each particular living thing seemed to be fitted to live under certain conditions and only under those conditions. Our desert plants grow best in sand and when it is hot and dry like the deserts from which they originally came. Our goldfish would certainly be very unhappy if they were taken out of the water and it would not be long before they were dead. Our pet canary would be equally unhappy if we tried to keep it in a screened tub of water. Even our pet dog or cat would resent a change of living from the conditions to which it was used.

Wherever we go, we are constantly seeing examples of the fitness of living things to succeed in the places where

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This gentleman has a hobby. How many of his pets can you find?

they are found. Biologists call these fitnesses *adaptations*. They are still uncertain just how these adaptations are handed down to new generations of plants and animals or just how it is that some plants and animals can adjust themselves to new conditions of life. We may learn more about this when we come to our study of biology. For the present all we are concerned with is to learn a little about adaptations in living things and to try to understand how we, as living things, are fitted or adapted to live in our surroundings.

PROBLEM I. WHAT ARE ADAPTATIONS AND WHAT DO THEY DO?

What Are Adaptations? Probably every boy and girl who reads these lines has seen a porcupine, if not alive,

then in a museum. At first sight you might wonder how in the world he uses his spiny covering. But if you had been out hunting and had your dog come in whining with his nose full of quills, you would not have to ask this question. Evidently the spiny covering gives protection to the otherwise defenseless animal. Or perhaps you have wondered how it was that some plants could stand severe drying while others wilted at once if they became dry. When you examined the leaves of the first plants, you probably found them either covered with tiny hairs or having thickened waterproof surfaces, which prevented rapid evaporation of water, while the plants that wilted quickly might have large, thin leaves with much surface from which to evaporate water. You may have wondered what the elephant did with its long trunk until you saw it use it for getting food or water. When we find in plants and animals structures which are fitted for some definite, useful purpose, we call that structure an *adaptation* and say it helps to fit or adapt the living thing to do some particular work.

American Museum of Natural History

When the porcupine becomes angry or frightened the quills stand out so that no enemy can touch him without getting hurt.

But plants and animals do not stop there. Often we find, in order to adjust themselves better to their surroundings, they do certain things. Some plants may twist or twine around objects, thus rising above other plants and so place their leaves in the light where they can make food. Animals hide in the

grass like the grasshopper, or burrow in the ground like the gopher, or withdraw into a protective shell like the snail or turtle, and in hundreds of ways perform actions that result in getting protection from their enemies or food for themselves. In shallow water at the seashore you may have caught little hermit crabs which protect their defenseless bodies by thrusting them into the cast-off shell of a sea snail, and retreating into it in time of danger. Such adjustive actions we also call adaptive, for they result in some good to the animal or plant.

Some animals are even adapting themselves like man to the changed conditions of modern life. The English sparrow, which used to subsist in our cities very largely on the partially digested seeds in horse and other manure, began to disappear in the cities when automobiles took the place of horses. Now we occasionally see the sparrows perched on the radiators of cars picking out insects which have been caught in these radiators as the cars went through the country highways.

Adaptations, then, may be structures which help the animal or plant to live, or acts performed by the animal or plant which result in better living conditions.

The Problems of Living Things. If you will think for a moment, you will see that living things, both plants and animals, have two big problems in life. The first is the care of themselves, the second the reproduction of young. The business of living means adjusting themselves to their surroundings so that they may get food, grow strong, and be able to protect themselves from their enemies. No matter what the living thing, be it a fish, a bird, a snail, a tree, or a weed, the problems of living are the same in the end.

Some Ways in Which a Bird Is Fitted for Its Life Work. Let us take, for example, a robin. You say such a bird is well fitted for its life. It has its legs provided with flexi-

ble toes which lock around the branch on which it perches. Study the wing of a chicken and you will see that the feathers with the wing form a light but efficient structure which offers resistance to the air when pushed against it. The feathers are so constructed that the tiny barbs which grow out from the quill to form the vane of the feather are all locked together by tiny hooks, thus making a strong, wind-resisting surface. Beebe[1] estimates that a single feather may have as many as 990,000 of these tiny hooks. You will also find that strong muscles are attached to the wing and fastened to the breastbone so that the wings can be moved rapidly. The bones of the robin are very light and it has a large heart and large lungs; all these things together help to make it an efficient flying machine.

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A magnified view of a feather. Can you find the place where the barbs are hooked together?

But we have just begun to mention the ways in which our robin is fitted to do his work. Think of the food he eats, then look at the beak and claws and see how efficiently they are built for the work they have to do. Think of the nest of the robin, of the fact that its eggs are hatched there and protected by the mother bird, that the little

[1] William Beebe, living naturalist, explorer, and writer.

ones are fed by the mother until they are able "to go on their own," and we see that in very many ways the robin is fitted or adapted to meet these big problems of living.

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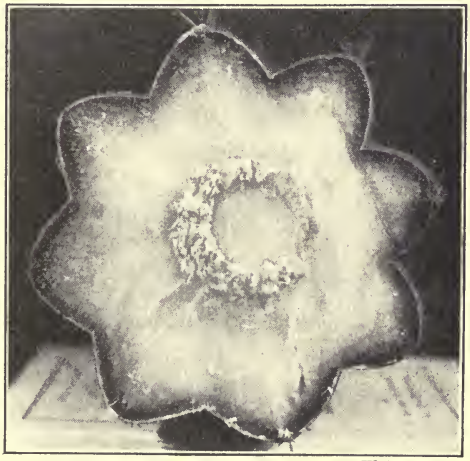
What kind of food does this bird eat?

How a Green Plant Meets the Problems of Living. It is not so easy for us to understand how a green plant meets its problems of life, for at first they seem so different from those of an animal. But are they very different? An animal has to have food in order to live; so does a green plant, only a green plant makes its food out of substances from the air and soil and the water it takes in. We must remember that both plants and animals have to breathe. They therefore need oxygen from the air. They both need a certain amount of heat and light, some more, some less. They must be protected and they must produce offspring if they are to be successful. The cactus is an example of a plant that has been successful in spite of unfavorable conditions. What special fitnesses or adaptations do we find which help it solve its problems of life? In the first place, instead of green leaves, we find spines. Leaves would wilt in the hot desert air, because they have large surfaces which allow water to evaporate from the plant. The cactus conserves its water by having a soft pithy stem which holds water and by having this

stem covered with a hard and corky covering which keeps the water in. By doing away with leaves entirely, the green stem instead of the leaves takes on the work of food manufacture. The plant is protected by its spines. No animal will eat it and it produces its young either by seeds or by means of buds from the parent plant. The cactus has solved its problems of life by means of its adaptations.

Success for Plants and Animals Comes through Adaptations. You all know how difficult it is to get rid of weeds in a garden. It seems as if they come up over night and that as soon as you pull one up, another takes its place. Weeds are successful plants, but why? If you examine a full-grown weed carefully, you will soon see why. Usually they produce very many seeds, and they have excellent means of scattering them. Look at the tumble weed as it rolls along, dropping seeds as it goes. Look at the dandelion or thistle with its seeds sailing through the air — or the stick-tight or cocklebur, with its fruits getting a ride by sticking to animals. Then weeds produce many more seeds than other plants. Sometimes a single plant forms hundreds of thousands of seeds. The seeds sprout under conditions unfavorable for other plants with which they



Wright Pierce

This cactus has been cut so as to show the watery pulp which is held inside the hard skin. What takes the place of the leaves in this plant? Why are there no leaves?

compete and they grow very quickly. They usually have deep, tough roots which help them to crowd out other plants by stealing their water supply. Choose some weed and note all the adaptations you can find. You will soon see why it is so successful in life.

Wright Pierce

What devices can you find for scattering seeds in this thistle?

We can also show that animal success is due to adaptations. Take any animal you know and name over the ways it is fitted for the life it leads. Hoofs, claws, furry or hairy coats, feathers or shells, wings, fins, flippers or legs, different types of teeth, all these and many more you might name as adaptive structures.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

life	death	survive	food
adjustment	leaves	fear	species
animals	structures	stems	break
rearing	protection	make	roots
acts	plants	care	elephant
nature	fitted	similar	spines

Adaptations are found everywhere in (1)____ and by means of them (2)____ and (3)____ are (4)____ to meet their problems of

living. These consist of getting (5)____, (6)____ from enemies, (7)____ to surroundings and the (8)____ and (9)____ of their young. Both plants and animals have the same (10)____ problems and have to meet them in (11)____ ways, although green plants have to (12)____ their food as well as use it. Adaptations may be (13)____ such as the proboscis of an (14)____ or the (15)____ in a cactus, or they may be (16)____ which help the plant or animal to (17)____ in its struggle for life.

STORY TEST

JOHN WRITES ABOUT ADAPTATIONS

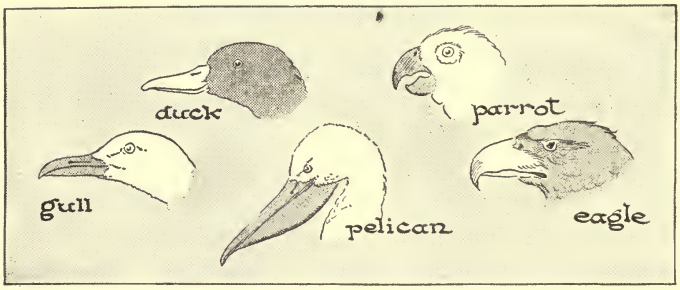
Read carefully and critically. List all the errors and suggest corrections.

Our teacher has asked me to tell you about the adaptations I found in my pet turtle. In the first place my turtle can live either on land or in water and has adaptations that fit him for both kinds of life. His claws, for example, are useful in swimming and the heavy shell helps him to sink when he goes under water. I think my turtle breathes under water, for he lets up a little stream of bubbles when he is under the surface and can stay under for a long time. But he always comes to the surface after a while, and I notice at night he stays on land and seems to sleep there. He has horny jaws which seem to be fitted for chewing his food. I have watched him eat an earthworm. He grabs it with his jaws, he tears it in two with his claws and then swallows the piece whole. My turtle can swim, although his toes are not webbed. I guess from this he is a water turtle.

PROBLEM II. HOW ARE WE FITTED TO LIVE IN OUR ENVIRONMENT?

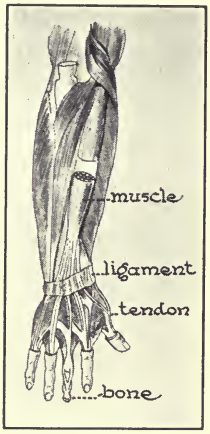
Man Is a Bundle of Adaptations. It is a common saying that man is a bundle of adaptations. Did you ever try to prove it true or false? Think of your own life and the wonderful ways in which your body is fitted for the work you do. You walk and run and jump and swim without giving much thought to the mechanism of the human machine. But if you examine any part of the body at all carefully, you will be amazed to find the numerous adaptations that exist in it. Take,

for example, such a simple act as walking. Simple, but is it? So many parts of the body act together — muscles, bones, nerves, heart, lungs, sense organs, and the master of them all, the brain — that what seems a simple act is found to be very complicated. You cannot with the little knowledge you have at this time explain such an act. But take something you can see and try to find adaptations there. Have you ever thought how wonderfully your hand is adapted to the work of holding objects, such as a pen or pencil? You know in a general way that it is a complicated mechanism, but do you know how it is built? For example, we have a bony framework, in which the individual bones are held loosely together in order to allow movement. But these bones are also bound together tightly enough so that they cannot get out of place. Not only are they held together, but each is separated from its next neighbor by a pad of soft elastic cartilage which gives a certain amount of play to the whole hand skeleton. Then each bone has attached to it scores of small, elastic bundles of muscles, some thirty-one in number, which will expand and contract. These muscles work in pairs, one relaxing as its partner contracts, and since they are attached to the bones, they give movement to them. But think of the numbers of muscles,



What kinds of food would you think these birds eat? Can you describe the kind of feet each of the above birds would have?

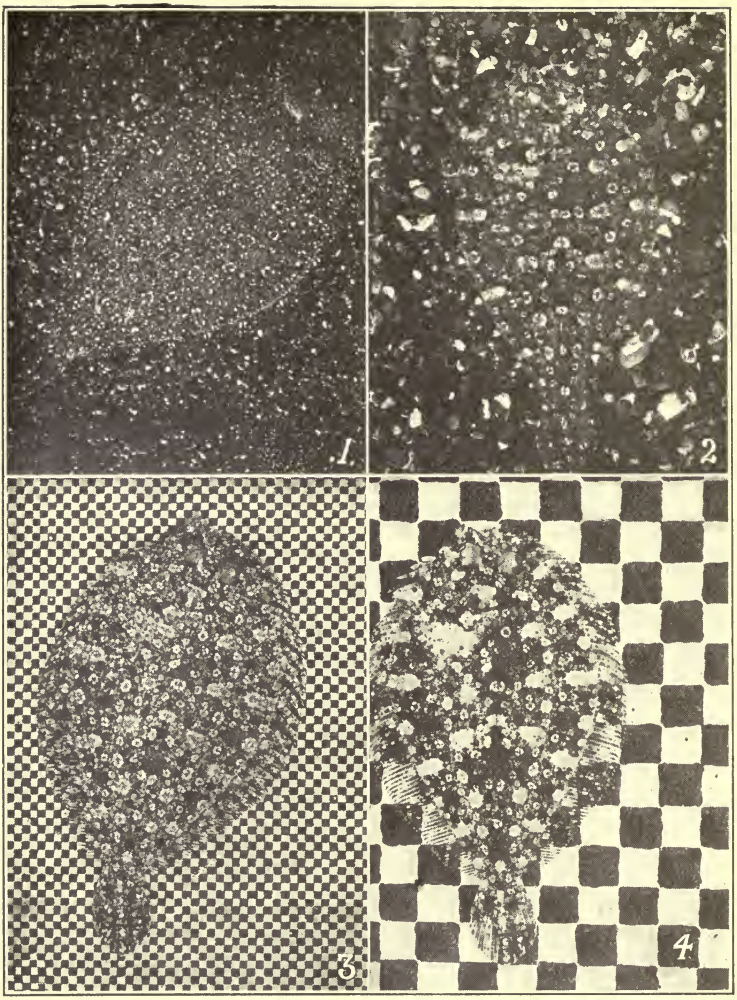
some large, some small, that go into this work of moving the hand and wrist. The muscles are attached to bones by means of cords called tendons. You can feel these cords in your wrist and you may have found that movement of the fingers is controlled by them. Study of the figure will show that these tendons are attached to muscles of the forearm so that movement of the hand is controlled by them. But we have again only begun to find the adaptations in the hand. All of the muscles must act together and must be directed by means of our nervous system. They must be supplied with blood containing food and oxygen (see page 376) if they are to do work. The skin must be sensitive so we may know when we touch anything. If we see the thing we touch, the eye plays a part. And now that we have mentioned all of these structures, we do not begin to understand how each part acts in grasping the pencil, let alone how we make the complicated and delicate actions which occur when we write our names.



Study this carefully and then explain how you can move your fingers.

The human body is full of adaptations, most of which are far more wonderful than those just described. To understand them thoroughly we must study physiology, a subject to be taken up in the senior high school. But we can see that the human body is a very complicated machine and that our job in life is to learn to run it efficiently.

Adaptations May Be Acts as Well as Structures. But animals often have ways of doing things which are adaptations. Certain tropical ants, for example, cut leaves from trees, carry the pieces to their nests, and there use



Dr. Francis B. Sumner

The photographs above show the results of experiments made by Dr. Francis B. Sumner of the University of California. He first photographed flounders in aquariums in which the flounders rested on different natural backgrounds of sand, mud, and stones. The fish always changed their color markings to blend with their background, as we see in figures **1** and **2**. What advantage would this be to the fish? He then changed the fish into aquariums having artificial backgrounds like figures **3** and **4**. What happened? Can you account for these changes?

them on which to grow tiny fungi; colorless plants that cannot make their own food. The fungi, not the leaves, are used as food by the ants. The habit some animals have of feigning death is one method of protection. Many birds which look like their surroundings will keep absolutely quiet on the approach of an enemy, thus escaping notice. Some animals can even change their colors or the markings on their bodies to blend with their surroundings. Man himself shows many examples of such adaptive acts. Have you ever thought that if babies did not instinctively suck soon after they are born, they could not live? Our lives depend on this one adaptive act. Can you think of any others?

Man, the Only Animal That Can Adapt His Environment to Suit Himself. We can find many examples of adaptation to the environment in plants and animals, but man alone seems able to change his environment to suit himself. We know that desert plants will not live long in the water and water-loving plants will soon die if placed in a hot, dry place. Sheep having long wool when transferred to a hot country like Cuba soon die, because the long wool unfits them for life in the hot, moist climate. But if man has to change his place of living from a cool to a hot climate, he dresses differently. In other words, he adapts himself to the new conditions. Some animals and plants can do this to a degree if the changes are gradually made; thus they may become slowly accustomed to changes in environment. But man is constantly changing his environment for the better. Look at what science has done to make living conditions more comfortable. We move from cold climates to warm ones by means of automobiles, railroads, steamships, or airplanes. We have fruits and vegetables at all times during the year because of refrigeration and cold storage. We are able to eat foods which were grown thousands of miles away because of rapid

transportation and refrigeration. We have learned to control disease so well that we have increased the number of years man can live. In other words, man is a thinking animal and as such has learned to control and improve his environment.

How We Make Adaptations. Have you learned to swim? You soon will if you have not already done so. You may remember how hard it was at first to keep your head above water and not to be frightened. You found that as you learned the different motions, you gradually improved, and then all at once you were able to swim. You will never lose this adaptation so long as you live. You have mastered this problem. When any one has completely mastered anything, like learning to swim, skate, read, or write, he has made an adaptation. So in this book we have given you a number of helps so that when you finish a unit of work, you may be sure that *you* have complete mastery of the subject. You have, for example, at the end of each problem, self-testing exercises which will help you find out if you have mastered the information in the pages just preceding. If you cannot fill in the blanks correctly, you should study those facts in the problem that you do not remember and then try the test again. Keep at it until you have mastered the problem. Then there are other tests which help you *apply* the information you have gained. You may know all the facts in the unit, but if you cannot apply these facts in the solving of simple problems, then you will not get very far in the mastery of the subject. Let us try to use these helps to gain the mastery which means success.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

change	improve	nervous	framework
adaptations	blood	structure	muscles
doing	friend	adapted	successful
cartilage	adapt	endocrine	efficiently
movement	muscle	food	drink
enemy	tendons	adaptation	unsuccessful

The human body has numerous complicated (1)____ which enable us to live (2)____. The hand is an example of an organ (3)____ for grasping or writing. It has a (4)____ of bones, loosely jointed with pads of elastic (5)____ between. Thirty-one (6)____ help to give (7)____ to these bones. Each (8)____ is attached to one or more bones by tough cords called (9)____. The whole apparatus is controlled by the (10)____ system. Adaptations are not always (11)____, they may be (12)____ ways of (13)____ things, such as getting (14)____ or escaping from an (15)____. Man is the only living thing that can successfully (16)____ the environment to himself. He can (17)____ it or (18)____ it, making an (19)____ in that way.

STORY TEST

Walter Writes about Adaptations in Man

Read carefully and critically. List all the errors and suggest corrections.

Animals and plants seem to be able to get along by means of adaptations. These are usually structures which make it possible for the plant or animal to live successfully where it happens to be. But man, who is able to travel and to change his place of living, does not have any such structures. He is the master of his surroundings and can change them to suit himself. If, for example, he is cold, he can put on more clothes or go where it is warmer. Of course a man has arms and legs, but they are in no way like the front and hind legs of a cat or dog. Since man can adjust himself so well to new conditions, he does not need adaptations.

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demon-

strations you have seen. These big ideas we call generalizations. For this unit they are as follows:

1. Adaptations are fitnesses for living in a given environment.
2. There are adaptive acts as well as adaptive structures.
3. Life depends upon adaptations.
4. Man shows many adaptations.
5. Man is the only living thing that can adapt the environment to himself.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of all statements you believe to be incorrect. Your grade = right answer* $\times 4$.

I. **Adaptations:** (1) make it possible for plants or animals to exist under certain conditions favorable to the adaptation; (2) make it possible for a plant or animal to live under any condition; (3) are adjustments; (4) are never found in the young but appear late in life; (5) are always structures.

II. **Adaptations make it possible:** (6) to obtain food; (7) to protect the offspring successfully; (8) to obtain money and fame; (9) to escape from one's enemies; (10) to adjust oneself to his surroundings.

III. **Some adaptations for life in the water are:** (11) claws; (12) gills; (13) fins; (14) slimy body; (15) heavy bones.

IV. **Some adaptations for life in a hot, dry climate are:** (16) electric fans; (17) spines instead of leaves; (18) in animals, thick hair to keep off the heat; (19) in plants, a thin body covering which easily allows the escape of heat; (20) sweating, which gets heat out of the body.

V. **Man can control or change his environment:** (21) by means of clothes; (22) because he can solve problems and thus adapt the environment to his needs; (23) through scientific discoveries; (24) because he has a nervous system; (25) because he is a "bundle of adaptations."

THOUGHT QUESTIONS

1. The trees near a smelter are found to be dying, although the condition of water supply, soil, light, etc., seem unchanged. Is this due to a lack of adaptation on the part of the tree?
2. Your pet goldfish is found dead in the aquarium which has just been cleaned and from which you removed all of the green plants? Is this due to a poor adaptation on the part of the fish?
3. A frog is green with dark spots on the upper surface and white underneath. Are these colors adaptations? If so, how?

REPORTS ON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. Adaptations of a boy or a girl for work in the classroom.
3. Compare the adaptations of the elephant and the giraffe.
4. Discuss adaptations in "Teeth of Animals."
5. How plant seeds are adapted for scattering.

SCIENCE RECREATION

1. Make a list of all the adaptations found in a pet dog or cat.
2. Make a list of strange or uncommon adaptations in plants.
3. Prove that success in the life of some plant or animal depends upon adaptations.

SCIENCE CLUB ACTIVITIES

1. Visit a museum to study adaptations.
2. Make a field trip to list adaptations in plants and animals.
3. Divide up an area between members of the club and see which member can give the longest list of adaptations for his area.

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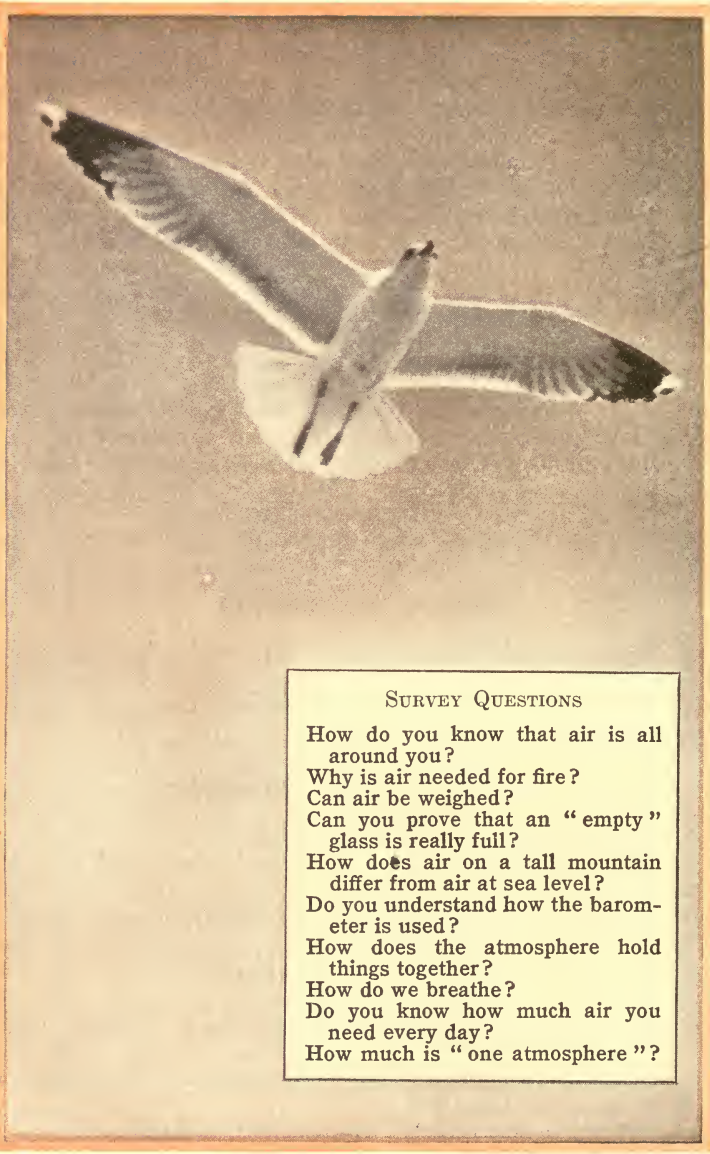

Survey Questions

How do you know that air is all around you?
Why is air needed for fire?
Can air be weighed?
Can you prove that an "empty" glass is really full?
How does air on a tall mountain differ from air at sea level?
Do you understand how the barometer is used?
How does the atmosphere hold things together?
How do we breathe?
Do you know how much air you need every day?
How much is "one atmosphere"?

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UNIT III

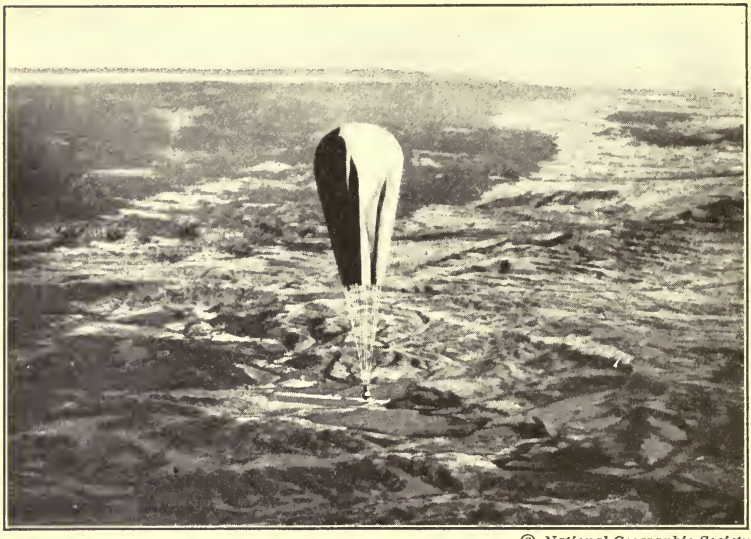
LIVING IN AN OCEAN OF AIR

PREVIEW

It is commonly said that " we live in an ocean of air." But you never see air as you do water and there is certainly no appearance of an ocean when you are in a room containing air, or even when you go for a hike in the open. What do we mean by this statement? We know that air exists, for we feel it when the wind blows; it holds up our kites, sails our boats, cools us when we are warm, and when it is heated, warms us when we are cold. In tires it holds up our automobiles. It works our compressed-air devices; turns wind-mills, stops trains by air brakes, and allows people to live and work under water in the caisson and diving bell. Sometimes in storms it blows down houses and wrecks ships. And, although we may not know just how we use it, air is necessary for life because living things breathe it. Have not Piccard and other high altitude explorers taken oxygen of the air with them into the stratosphere, and has not Beebe taken it into the ocean depths in order to exist there?

It has taken a good many people a long, long time to find out much about air. While the Greek philosophers knew something about it and even invented some devices that made use of the fact that air had weight, it was not until the time of Galileo[1] (1564–1642) that it was proved that air had weight. Galileo did this by first weighing a hollow copper ball and then forcing air into it until the air was compressed in the ball. He weighed it a second

[1] Galileo (găl′ĭ-lē′o).



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The start of the stratosphere flight above Rapid City, South Dakota. Do you know the use of any of the instruments contained in the gondola under the balloon?

time and found it weighed more. He concluded this greater weight must be due to the extra air in the ball.

Our knowledge about what the air is dates back a little more than a century, when Priestley, an Englishman, separated oxygen out of the air, thus showing it to be a mixture of gases. Then the Frenchman, Lavoisier,[1] discovered that oxygen causes things to burn and an Englishman named Cavendish shortly after found that carbon dioxide was a gas formed when things burned. Priestley discovered the gas that made up almost four-fifths of the atmosphere and Lavoisier named it nitrogen. Recently small quantities of other gases have been found to be a part of the air mixture.

As discoveries in pure science are followed by applications of science useful to man, so the discovery that air pressure could be measured by an instrument called the

[1] Lavoisier (là′vwà′zyā′).

barometer started a long line of applications in the use of this instrument. The heights of mountains can be measured and weather changes can be foretold. The air pilot's altimeter is a type of barometer with a scale marked off in distances above sea level. The various things that scientists have found out about the air have been used in thousands of ways to make life more efficient and comfortable.

PROBLEM I. WHAT MAKES THE AIR USEFUL TO MAN?

Demonstration 1. Does Air Occupy Space?

Cut the bottom from a narrow-necked pint bottle.[1] Stretch the open end of a rubber balloon over the mouth of the bottle. Close the clamp over the neck of the balloon near the neck of the bottle.

Thrust the large open end of the bottle down into a quart jar half full of water.

a. Does water enter the bottle?

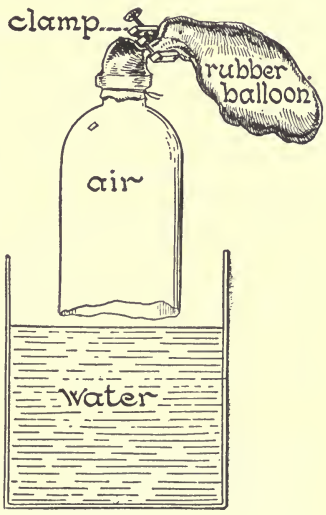
b. Does the level of water change in the jar?

c. Explain.

Open the clamp on the rubber balloon. Notice three things that happen as a result.

d. Record these three changes.

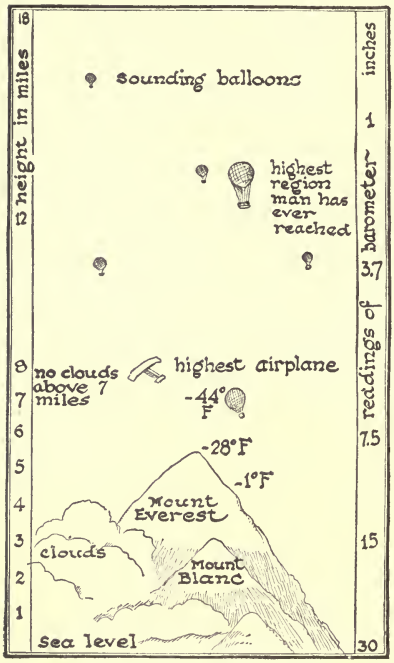
e. If you find any evidence to prove that air occupies space, explain what it is.



Air Is All about Us. *Air* makes an envelope for the earth that extends high above us. Those of us who have climbed a 10,000-foot mountain know how hard it is to breathe as we near the summit. We say that the air has become thin. As a matter of fact if one could rise above sea level at will, he would eventually pass out of the atmosphere into space where

[1] Process explained on page 77.

there is no air. Air is found in water, as can easily be shown by bringing a glass flask of water nearly "to a boil." Bubbles of air will be seen to form on the inside of the flask. Air is also found in the soil, as can be seen by packing a tumbler about half full of soil and then adding water. Notice what happens when the water soaks into the soil. We can easily show that air fills the space in a vessel we call "empty." The simplest experiment is to push an inverted glass into a vessel of water and see if anything keeps the water from filling the glass. A more interesting way of showing the same principle is used in the demonstration on page 45.



How our atmosphere tapers off. It is 30 times as dense at sea level as it is 15 miles above.

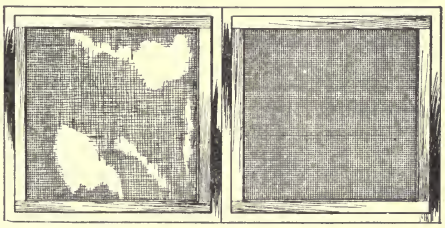
The Atmosphere Exerts Pressure. The atmosphere is the entire body of air which surrounds the earth; the term "air" is commonly used when we refer to any small part of the atmosphere. Since the atmosphere gets thinner and thinner as one rises in it, a cubic foot of space at the earth's surface must have more air in it than a cubic foot of space several miles above the surface. While some people say that the air reaches a distance of 200 miles or more above the earth, about half of it is below the tops of mountains $3\frac{1}{2}$ miles high. But wherever we are, the

atmosphere is always pressing upon us and upon everything it touches.

Air Is a Mixture. In the latter part of the eighteenth century several men of science, working in their laboratories, proved that air consists of several gases, the most important of which are oxygen, nitrogen, carbon dioxide, and water vapor. Among other substances in the air are the gases, argon, neon, and helium. Besides this, there is a variable quantity of dust, consisting of pollen, soot, soil, and many other tiny particles of matter. Oxygen forms about one fifth and nitrogen nearly four fifths of the air near the earth.

What Causes Rust. You have all seen examples of rusting: the brown flakes and yellow dust on unpainted iron fences, unused rails, your knife on a fishing trip, on a tin can left for a time in a damp place.

Since unprotected iron surfaces are so easily acted upon by the oxygen in moist air, exposed surfaces of iron are covered with material which keeps the air from them. A "tin" can is iron with a thin wash of tin on the surface. But you know that a tin can will rust. This is because there are microscopic openings in the tin covering through which air reaches the iron. A "tin" roof again is tin-coated iron. To protect it, various paints may be applied. Steel bridges costing millions of dollars are preserved for many years by painting at proper intervals. When iron is dipped into molten zinc and withdrawn, a coat of zinc clings to the iron, making what is called galvanized iron. This protects the iron even better than the coat of tin.



What is rust and what causes rusting? How could the screen have been protected from rust?

Oxygen — a Harmful and Useful Agent. There are few useful things in this world which cannot at the same time be harmful or objectionable. The air is no exception to this general statement. Man makes iron fences, iron bridges, iron mosquito netting, and sheet iron for cans, dishes, covering for boats and roofs of dwellings. Sooner or later the oxygen of the air may combine with the iron, making a worthless mass of iron oxide, without even strength enough to hold itself up.

Wright Pierce

Why are iron pipes sometimes unreliable carriers of water?

What Substance in the Air Aids Burning? If one were to place three lighted candles on the table and at the same instant cover them with three jars of different sizes, would the candles all burn for the same length of time? You know what will happen: the candle in the largest jar burns the longest. The largest jar has the most air, and there is something in the air that helps things to burn.

Demonstration 2. What Gas Helps Things to Burn?

Fill two wide-mouth bottles, one with oxygen and the other with nitrogen.[1] Place them mouth up, but cover with a small glass plate.

1. Plunge a flaming wooden splint into the nitrogen. Result? Plunge a glowing coal on the end of the splint in the nitrogen. Result?

[1] Prepare nitrogen by the following method:

Put bundle of wet steel wool in wide-mouth bottle, put mouth down in jar of water. Next day remove wool while under water. Close mouth of bottle, remove from water, and set right side up. The gas in the bottle will be practically all nitrogen.

2. Plunge the glowing end of a splint into oxygen. Remove instantly and cover the jar. Result? Twist a wire around a small bundle of steel wool. Heat the steel wool in a flame and immediately plunge it into the oxygen. Result?

The results are so striking that there is no doubt what it is that helps things to burn. The two gases, nitrogen and oxygen, appear to have opposite properties. Nitrogen quenches a fire just as water would, but oxygen causes it to burn with greater force. Air supports a flame because of the oxygen in it. But things do not burn as fiercely in air as in pure oxygen because of the large amount of nitrogen in the air.

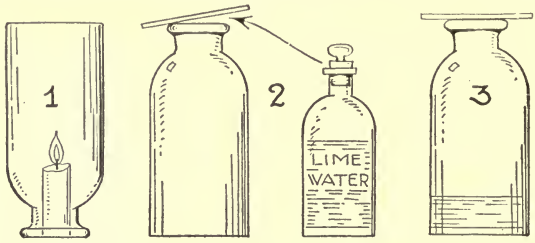
What Is Oxidation? When a substance combines with oxygen, the process is called oxidation. When this combination of a substance with oxygen results in a flame, the process is called combustion. Iron combines with oxygen when it rusts, but there is no flame; therefore this process is oxidation but not combustion.

What Is a Flame? Flame is defined as a burning gas. It is easy to understand this in the case of burning manufactured or natural gas. When oil burns, it must first be changed to a gas by heat before there can be any flame. Have you ever noticed when a candle burns that the wax melts and is taken by the wick up to the flame? There it is changed to a gas which burns, and in doing so, produces the candle flame. If you hold one end of a glass tube in the center of a candle flame so as to conduct gas through it, the gas will burn with a flame at the other end.

Demonstration 3. What Substances Result When a Candle Burns?

1. Bring a dry pint jar down on a burning candle. When the candle goes out, remove the jar and quickly close with a glass plate or cardboard. What appears to be on the inside surface?

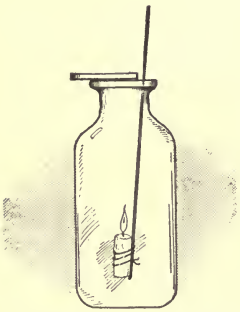
2. Pour 50 cc. (about 2 oz.) of limewater into the jar. Close and shake. There is only one common gas, carbon dioxide, that



causes limewater to become milky.[1] If we find a change from clear to a milky liquid, what does it prove?

What substances does this demonstration suggest are produced when oxygen of the air combines with the candle?

It may seem strange to you to find that water comes from the burning of a candle. But if you know that oxygen in the air is a gas that supports the burning of the candle, then it is easily understood. The candle contains hydrogen and carbon. Both of these elements will burn. The hydrogen unites with oxygen and forms water (H_2O). The carbon unites with oxygen to form carbon dioxide (CO_2). These two compounds also result from the burning of other substances containing hydrogen and carbon, such as gasoline, oil, coal, and wood. They are, therefore, always present in the smoke coming from chimneys.



Where will water appear in the jar after the candle burns for a short time? How do we know it comes from the candle?

The Air Is Useful in Many Ways. The air of the atmosphere was just as useful to Columbus as was the water of the ocean, for while the ocean buoyed up his

[1] To show that it is carbon dioxide that turns limewater milky, generate the gas by adding hydrochloric acid to marble chips in a test tube and conduct the gas through a delivery tube, making it bubble through limewater in another test tube.

vessels, it was moving currents of air, or winds, that carried him to a new and unknown land. Today the air buoys up airships, and propellers pushing against the air can make the airships move without the aid of a wind. It is not merely in mechanical ways that air is important. There are many vital chemical processes dependent upon it. Breathing animals take oxygen from the air. If the water were all driven out of plants, by far the greater part of the material left would be carbon taken out of the air by the plant. Since plants are essential for animal life, we can truly say the air is no less important, for without air there would be no plants; nor would there be animals.

What causes this boat to move?

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

oxidation	air	extinguish	fire
oxygen	heat	combustion	dioxide
out	rust	nitrogen	oxide

carbon	acids	kindled	cold
water	weak	chemical	put
vapor	light	action	carbon
melt	germs	hydrogen	dark

It is fortunate for us that (1)____ constantly surrounds us. If there were no (2)____ in water, fish would die. The part of the air that helps things to burn is (3)____ and (4)____ which makes up four fifths of the (5)____ will (6)____ a flame. Moist air causes iron to (7)____ in a process called (8)____. Combustion is (9)____ in which both (10)____ and (11)____ are produced. Two important compounds produced when a candle burns are (12)____ and (13)____ (14)____. Limewater is used to test for the presence of (15)____ (16)____.

STORY TEST

Ruth Tells Why Air Is Useful to Man

Read carefully and critically. List all the errors and suggest corrections.

Air is the medium which extends far out into space from the earth, and if man ever reaches the moon, it will be by sailing through the air which connects the two bodies. Two bodies of matter cannot occupy the same space at the same time. It is for this reason that there is no air in soil or in water. Air is a mixture. Oxygen and hydrogen make up about 97 per cent of the air. If there were no carbon dioxide in the air, fires once started could not be extinguished. A burning candle adds oxygen and water to the air. Iron can be burned in oxygen. The combustion of iron is called rusting, and the burning of coal is rapid oxidation. Paint is used on iron bridges because air hardens the paint and makes a tough coating, which increases the strength of the bridge. Limestone is used as a test for carbon dioxide. Air supplies man with helium for airships, and carbon dioxide for charging soda water. The most important use of air is for airplanes and airships.

PROBLEM II. OF WHAT IMPORTANCE IS ATMOSPHERIC PRESSURE?

Why Air Can Exert Pressure. Have you ever noticed how dust and other light objects, as loose papers, will rush

into the space immediately behind a swiftly moving train? It is the pressure of the atmosphere that causes air to

Galloway

Why does this rapidly moving train pick up dust and papers directly behind the observation car?

move into a place from which any object has been removed, and moving air can move other bodies with it. If we remove the air from a closed space, the air will try to get back in, and failing, will perhaps push the walls together. When the air is pumped out of an ordinary rubber tube which has one end closed, the tube is pressed until it is flat, just as if a heavy weight had been laid upon it. A ten-pound block of stone resting on the table presses down upon the table because the force called gravity is pulling on the stone. Any body of matter which has weight will in a similar way exert force upon anything that is under it. This leads us to ask, "Does air have weight?"

Many years ago Galileo, who was the first man in the world to make extensive use of experiments to answer his questions, was the first to weigh air. While he used a copper globe as a container, you could do it in your own

GALILEO GALILEI, 1564–1642.

AS a boy, Galileo, as he liked to be called, showed great promise. He was a keen observer and a straight thinker, as his companions soon learned. We all know the story of how in the Cathedral of Pisa he noticed that as the great lamp which hung from the arched roof swung back and forth it always took the same length of time for its journey. This gave him the discovery of the laws of the pendulum.

Later he worked out the law of falling bodies by letting two balls of unequal weight fall from the top of the leaning tower of Pisa. They reached the bottom at the same time, thus disproving the belief of Aristotle held for over 2000 years, that heavier bodies fall faster than lighter ones. He also made the first thermometer and learned many new facts about light, heat, and air pressure.

But we remember him best for his improvement of the telescope and his discoveries in astronomy. He was the first to see that there were moons revolving around Jupiter, to discover the rings of Saturn, and to observe the rotation of the sun. The movement of sun spots across the sun's disk proved to him that the sun revolved.

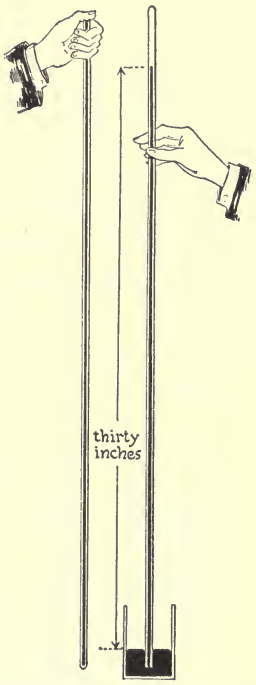
Galileo weighed air and started his pupil Torricelli upon many experiments involving air pressure and vacuums. It was while engaged in this work that Torricelli produced the first mercury barometer.

Galileo was one of the first men to make use of the scientific method and to apply the test of the experiment in order to learn new facts and to prove the unchangeable relation between cause and effect.

home with a football or a basket ball. Suspend a yardstick at its middle point. Hang a fully inflated football from one arm about twelve inches from the center. The rubber tube should extend and be closed with a clamp. Balance the ball exactly with weights on the other arm. Open the clamp to allow the excess of air to escape. The ball will rise, showing that it is lighter and has lost weight. If it has lost air and weight, what is your conclusion about whether air has weight or not?

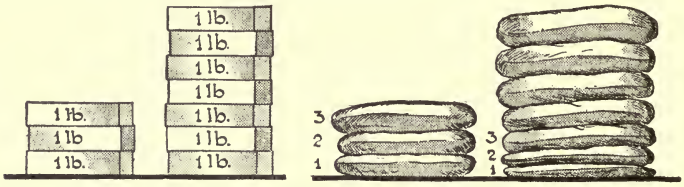
Atmospheric Pressure. Since air has weight, it must exert force upon the objects upon which it rests like all other matter. Torricelli (tŏr′rē-chĕl′lĕ), a pupil of that great Italian scientist, Galileo, proved that air exerts pressure by means of the following experiment.

He took a glass tube about three feet long, closed at one end, and filled it with mercury. Then holding his thumb over the end, he inverted it in a cup of mercury. The column of mercury dropped until the height was about thirty inches above the mercury in the cup. This showed that the pressure of air on the mercury in the cup was sufficient to balance a thirty-inch column of mercury. Torricelli called the instrument he used for measuring air pressure a *barometer*. Later, when the barometer was carried to the top of a mountain three thousand feet high, the mercury column dropped about three inches. Can you explain why?



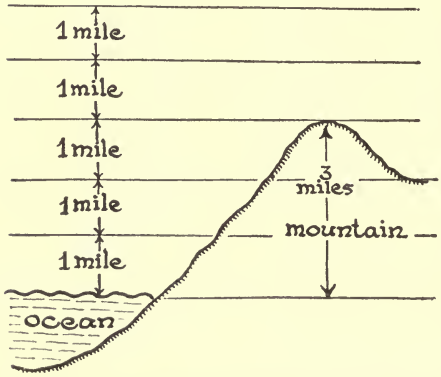
Why does the column of mercury remain at a height of 30 inches?

If you had seven bricks piled one upon the other, how will the pressure under the third brick from the top compare with the pressure under the bottom brick? Just



Observe that the matter in the pillows at the bottom of the pile is crowded into a smaller space, thus making it denser. In this respect which is more like the conditions in the atmosphere, the bricks or the pillows?

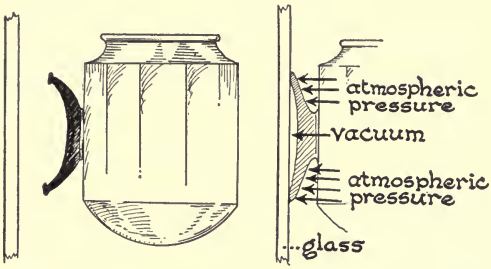
as seven bricks exert more pressure than three bricks because they have more weight, for that same reason air at the level of the ocean will exert more pressure than air on top of a mountain. We would then expect the pressure at a seaport like New York to be greater than at a mountain city like Denver. The pressure at seaport towns is 14.7 pounds per square inch, or enough to hold a column of mercury 29.92 inches. It is common practice to regard 30 inches for the barometer or 15 pounds per square inch as standard atmospheric pressure at sea level.



Does the air press down with as much force at the top of this mountain as it does at the bottom?

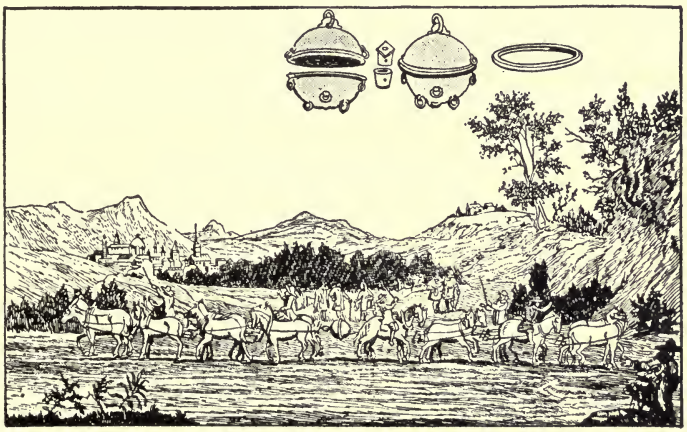
How the Atmosphere Holds Things Together. If you lay one square of glass upon a second glass, you can easily pick the first one off from the second. But if you wet the two pieces of glass and place them together, the water takes the place of the air between the

pieces of glass and fills the entire space. When there is no air between the pieces of glass, there is no air pressure tending to separate them, and it is with great difficulty that you can pull apart the two pieces. This is because the air on the outside is pressing them together with a force of about fifteen pounds to the square inch. After you fill a bottle with water, put a small piece of wet paper on top and invert it, what happens? Why? Application of this principle is made in the disks used for coat hangers, supports for shelves in display windows, and the ash tray that clings to the wind shield of the automobile.



Explain this diagram. Can you mention any other devices that make use of this same principle?

A very famous experiment was tried in Magdeburg (mäg′dē-bo͝orĸ), Germany, in 1650. Two metal hemi-



Explain this renowned experiment with the Magdeburg hemispheres.

spheres, about two feet in diameter, were placed together, making a hollow ball, and the air was pumped out of them. The atmosphere held these two hemispheres together so tightly that eight horses on each side were unable to pull the hemispheres apart.

Importance of Atmospheric Pressure. The common uses of atmospheric pressure are varied and numerous. From the act of breathing to the measurement of the height of mountains there are thousands of ways in which man makes use of atmospheric pressure. It assists in the pumping of water. The barometer tells how high aircraft rise, and assists in foretelling weather. Variations in atmospheric pressure make our winds and storms and cause droughts and floods. The success of farmers' crops or of curing foodstuffs in the open may depend upon atmospheric pressure. In the development of life from the beginning, animals and plants on the earth have been accustomed to a certain atmospheric pressure, as can be seen when deep-sea fish are rapidly brought to the surface. Such fish sometimes actually explode when they are drawn suddenly to the surface of the water, where atmospheric pressure is much less than that to which they are accustomed. People who go to the tops of very high mountains fail to get enough oxygen, and the decrease in air pressure causes bleeding from blood vessels which break under the lessened pressure.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

weight	Aristotle	water	space
support	vacuum	push	speed
height	pounds	pressure	Torricelli
sea	atmospheric	weather	mercury
ounces	square	height	mountain
cubic	force	vacant	Galileo

Air can exert pressure because of its (1)____. At (2)____ level the pressure is 14.7 (3)____ per (4)____ inch. (5)____ was the first to measure the (6)____ of the atmosphere. He did this by finding how tall a column of (7)____ the atmosphere would (8)____. Atmospheric (9)____ decreases as we go up from the surface of the earth. The barometer, by measuring (10)____ (11)____, is useful in (12)____ forecasting, in measuring the (13)____ of (14)____ and to tell the (15)____ of an airplane.

STORY TEST

ARTHUR TELLS ABOUT THE PRESSURE OF THE ATMOSPHERE

Read carefully and critically. List all the errors and suggest corrections.

Classmates: I have been reading about the pressure of the atmosphere. Pressure is the force exerted by any body on one unit area. We speak of anything as being "light as air" because air has no weight. However, when I hold my open hand out horizontally, the air or atmosphere is pressing down on my hand with a force of more than 100 pounds. Galileo made the first barometer with a long glass tube and mercury. He found that the air pressure was about 15 pounds on every square foot of area at sea level. As one goes higher into the air, the pressure increases roughly in proportion to the elevation. A barometer can be used to measure the height of a mountain, but an altimeter is used to tell how high an airplane is above sea level. A barometer could be used to tell the altitude of an airplane, but the altimeter could not be used to measure the height of a mountain. When a glass of water is inverted so that the water runs out, the glass has nothing in it and is said to be "empty." A space that contains no matter is a vacuum. When you drink soda water through a straw, you pull the liquid up by suction. The air is denser in Death Valley, which is below sea level, than at sea level, but less dense than on a high mountain. When an automobile moves, it must push the air away to make a space to move into. The air pressure on the front of a moving auto is balanced by an equal air pressure on the rear surfaces.

PROBLEM III. HOW DO WE USE AIR?

How Is the Air Used? Most boys and girls would not think very long over this question, but what answers would they give. For breathing, most would say, but not

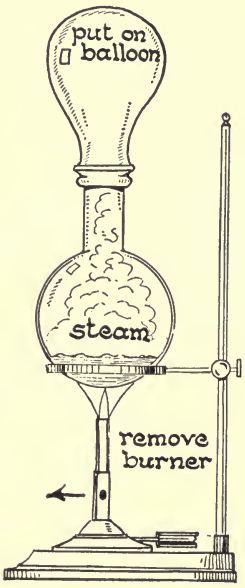
many could tell *how* the air was used. It might be easier to answer the statement that air helps us fly our kites, sail our boats, hold up toy balloons, and turn toy windmills. Practical boys will at once think of air in bicycle

What holds a kite up? How do you get a kite up in the air? Why does the boy run with his kite?

and auto tires, while a girl might think of a cool breeze produced by means of an electric fan. Perhaps someone knows how the air helps fill a fountain pen or a medicine dropper or at least how it helps you to drink soda water through a straw. Let us look into some of these uses of the air and see if we can explain them scientifically.

What Is a Vacuum? Air not only fills what we call "empty" bottles, but it fills our houses and all outdoor space. The Greeks had a saying, "Nature abhors a vacuum," which was handed down from generation to generation. They knew, as we know, that it is difficult to keep air out of any space. If air is pumped out of a jar so that there is nothing in it, we say a vacuum is

formed. Actually we do not produce a complete vacuum, for there is always a little air left. It is practically impossible to remove all matter from a space, hence we call any space from which nearly all the air has been removed a vacuum.



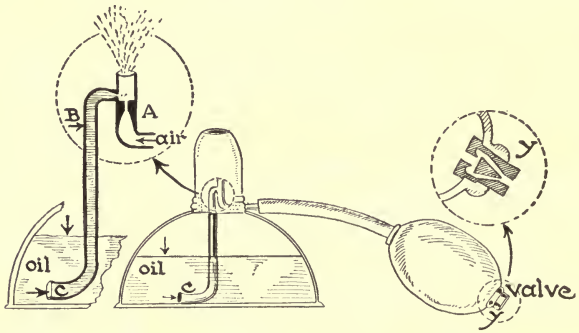
Demonstration 4. Making a Vacuum by Condensing Steam in a Glass Flask.

Stretch the neck of a rubber balloon over the neck of a flask which is filled with steam. As the steam condenses, a partial vacuum is formed. Explain the action.

A Useful Vacuum Maker. The demonstration shows how the atmosphere presses towards a vacuum. There are simpler ways of making a vacuum than by condensing steam. The rubber bulb is a common and useful device for making a vacuum. After a vacuum has been made, it is a simple matter to get the atmosphere to work for you. Take the medicine dropper. Place the open end under water; squeeze the bulb. Did anything come out? Release the bulb. The elasticity of the rubber makes it spring back to its original size. The air that was squeezed out has left some room in the tube so that the atmospheric pressure on the water outside the tube can push water up into the tube. A fountain pen has a rubber bulb which is squeezed by a lever to make the vacuum, after which atmospheric pressure lifts the ink into the reservoir of your pen.

The Atomizer. Another use of the rubber bulb in producing movement of a liquid is in the atomizer used for perfume or for spraying your throat. This bulb has a valve so that it can send a series of puffs of air through. As each puff of air is forced across the open end of the

tube *B* some of the liquid comes out of *B;* as the pressure is decreased inside the tube, atmospheric pressure on the surface of the liquid inside the container pushes it up through *C*. When this liquid meets the current of air from the bulb, it is caught and separated into a spray of finely divided particles which are carried along with the

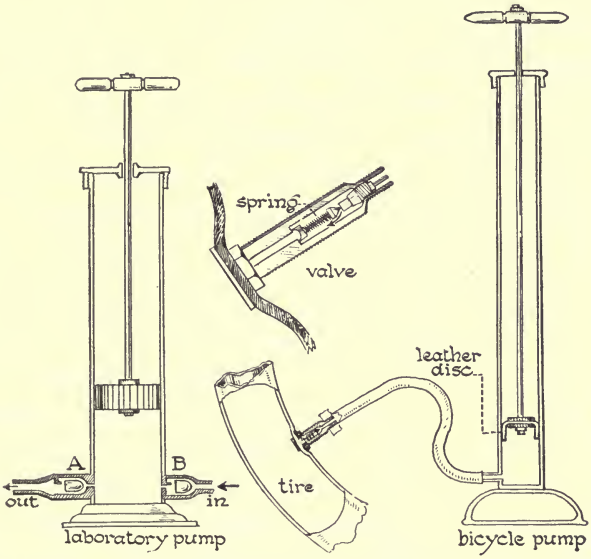


How does the liquid rise from *C* to *B*? What causes the fine spray above *A*? What is the use of the valve *y*?

current of air. Many spray-guns for spraying liquids to kill garden insects and house moths work on this same principle, but use a cylinder and piston instead of the rubber bulb to produce the current of air.

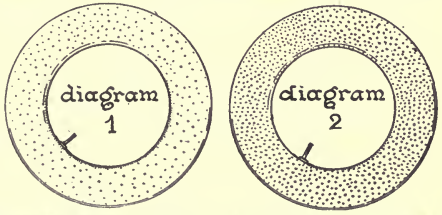
The Air Pump. The hand air pump used to fill bicycle and auto tires has a piston with a leather facing so arranged that when the cylinder is full of air and the piston is pushed in, the air inside is compressed and pushes the leather against the cylinder wall so tightly that none can escape there. The outlet pipe is coupled to the tire stem. There is a valve in the tire stem which allows air to go into the tire but prevents it from coming out. When the air in the cylinder is under greater pressure than the air in the tire, it will pass from the cylinder of the pump into the tire. A basket-ball or a football pump must have a valve because there is no valve in the tube of the ball.

Why Air in a Tire Will Support a Load. What can be more useless than a flat tire? And how different the tire becomes after it is pumped up. Let us see what holds the tire out after more air is forced into it. You



Explain the movement in the valves *A* and *B* during the upstroke and the downstroke of the piston. What serves as an inlet valve in the bicycle pump?

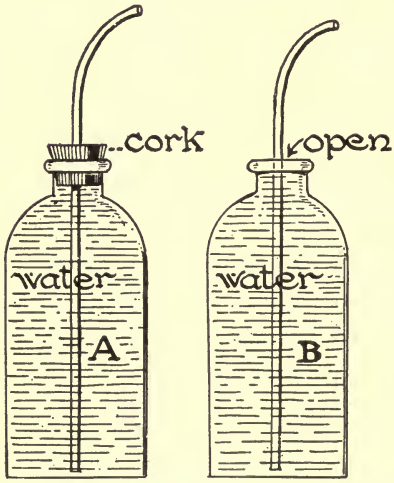
remember that all matter consists of molecules in motion. Study diagram 1. Here the dots represent molecules of air, which are constantly moving. They bump into each other and against the wall of the inner tube. As each molecule hits the tube it gives a push. As a stream of the molecules are pumped into the tube, they are squeezed in close together and in consequence more and more



Explain what happens in a flat tire. Why does the tire stay up?

of them hit against the tube (see diagram 2), thus increasing pressure against it. Thus air pressure causes the tube to bulge out and we say "the tire is up." The tire stays up as long as it holds these gas molecules, and it goes down when the number of the molecules decreases so that there are too few to strike enough blows to maintain the pressure.

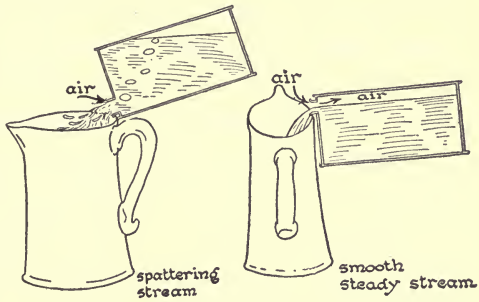
A Household Use of the Vacuum. Recall the demonstration in which steam drove the air from a flask. When the steam condensed, the pressure in the flask was less than that of the atmosphere. In canning fruit and vegetables, the heat used produces three important results. It cooks the food, it kills the bacteria that might cause it to spoil, and it produces steam that drives all the air out. If the cover is put on before the water present cools, after the cooling and condensing of the steam a vacuum is formed. Outside atmospheric pressure, being so much greater than the pressure inside, presses the cover on so tightly that no germs (bacteria) can get in to harm the food.



Try sucking water from each of these bottles. Which gives the better result?

How to Empty a Liquid from a Vessel with a Small Opening. Many people make no use of their science outside the classroom because it is difficult for them to apply scientific facts and principles to new situations. Did you ever try to suck water out of a bottle that is full of water having a glass tube passing into it through a tightly fitting stopper? Try it if you think you can do it.

You can make a vacuum in the tube, but there is no force to push the water up. If you loosen the stopper, air can get in and with its force of fifteen pounds to the square inch lifts the water out as air replaces it in the bottle.



Read the paragraph and explain the diagram.

Have you seen anyone pour oil, sirup, or other liquids out of a gallon tin can having a flat top? They usually tip the can so that the opening is at the lowest part of the top surface. Study the diagram. Do you see that air must enter and push upward through the liquid in order to displace it? The flow is jerky and irregular, often spattering. When the can is lifted up, the liquid runs over the top of the can. How can one prevent the bubbling of air up through the liquid and so make a more even flow? This is done very simply. Hold the can with the outlet at the highest level in pouring. The liquid will then flow out and the air will pass in above the liquid. Some people prefer to punch a hole through the top at the corner opposite the outlet and then the liquid passes out without interference just as it does from the evaporated milk can when two holes have been made in the top. If you do not understand why this helps to make an even flow, ask to have it explained.

Man's Use of the Air. The most important use of the air is for breathing. We may go without food for weeks, without water for days, but we cannot go without air for much more than a minute. Try to see how long you can hold your breath. It is said that divers for pearls have been known to remain under water for two or three

minutes without breathing, but this is the limit of human endurance. Incidentally the air all around us presses upon every square inch of our surface with a force of nearly fifteen pounds to the square inch. This great force is necessary to hold us together because the fluids within us are pressing outward with an equal force. Can you imagine what would happen to a person who was suddenly thrust into a vacuum? Would he die in a short time because of lack of air for breathing or would something startling happen quickly? Discuss this with your classmates and your teacher.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

fan	coals	piston	air	atmosphere
bulb	reduce	sail	mass	greater
into	winds	less	pushed	breathing
cools	pressure	pump	walls	vacuum
refrigerator	row	more	valve	volume
heats	tube	increase	weight	space

Air in motion is useful in many ways. The electric (1)____ cools us on hot days. A fan in the automobile (2)____ the radiator. Natural air movements as (3)____ may move (4)____ boats and kites. Artificial conditions to make the (5)____ work for us are found in devices which are capable of making a (6)____. For example, squeezing the (7)____ of a medicine dropper and then releasing it produces a (8)____. If this space containing the (9)____ is open to a liquid, the pressure inside the tube over the liquid is (10)____ than the pressure of the (11)____ on the liquid outside the tube; as a result the liquid is (12)____ (13)____ the tube. Another common device to (14)____ the pressure and so make a (15)____ is the cylinder having a (16)____ which can be moved back and forth in it. The bicycle or tire (17)____ is an example of this. Air molecules always are pushing against each other and against the (18)____ of whatever is holding them, so the more air we pump into a tire, the (19)____ the load it can hold up. The most important use of air is for (20)____.

STORY TEST

Ralph Explains How He Uses Air

Read carefully and critically. List all the errors and suggest corrections.

I began the day with a sneeze. I used air for that. I did not use air during the night: I never do. I opened the faucet to get water for washing, the atmospheric pressure made the water run out. I pressed the tube to get tooth paste upon my tooth brush, air pressure made the paste come out. I squeezed the bulb of a sprayer to use an antiseptic for my sore throat, pressure of the air lifted the liquid out of the bottle. Coffee was made for the older folks for breakfast; in the coffee percolater pressure of the air made the liquid spurt out over the coffee. After breakfast I had target practice with an air rifle and with vacuum-tipped arrows, both of which make use of atmospheric pressure. I tried to fly my kite but the atmospheric pressure was too great and I had to give that up. It was a sunshiny day with absolutely no wind; the water was calm — just the time to have a safe trip in my sail boat. I took a friend across the lake but had to tack coming back. We pumped up an inner tube to take in with us while bathing. We made use of the air in the tube, but atmospheric pressure was not needed as we forced the air into the tube by means of a piston pump. We went home in an automobile. I noticed a fan under the hood and I think it drew air into the cylinders so the gasoline could burn. James and I had a race today. We had gallon jugs just alike, both filled with water. We were to see who could empty the water out first. I tipped mine upside down and held it still. James tipped his as I did but gave it a whirling motion at first to make the water whirl. I won. I started writing this by electric light, but the lights went out and I am finishing by candle light, but the wind blows the flame out every little while. If it were not for the difficulty of lighting, the candles could be sealed in a glass bulb just as the wires of the electric lamp are. They would not blow out so easily then.

PROBLEM IV. HOW DO WE BREATHE?

A Day's Air Supply. Did you ever stop to think how much air you take into the body in 24 hours? At the smallest estimate it is over 60 barrels. This seems a lot of air, for most of us could get inside of a single barrel.

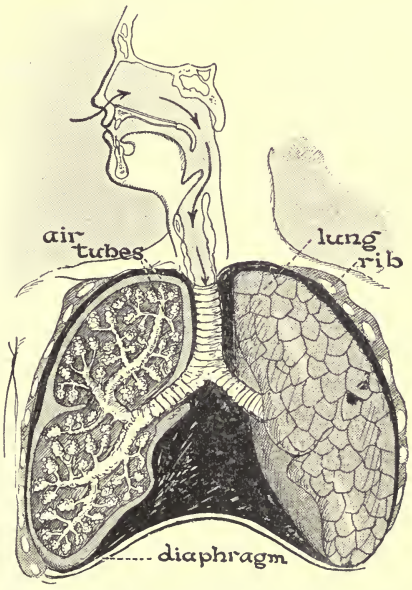
It is possible for you to find out roughly the amount of air you use by the following home experiment: Count the number of times you breathe per minute. It will likely be somewhere from 12 to 16. The average breath is 30 cubic inches. Considering your own size, about how many cubic inches of air do you think you take in at a single breath? Find the amount for one day by multiplying the number of breaths per minute by the volume of each breath and then by the number of minutes in an hour and by 24, the number of hours in a day. A barrel holds about $31\frac{1}{2}$ gallons and there are 231 cubic inches in a gallon. You take much more air when you are exercising, since you breathe more rapidly and take deeper breaths. Then, on the other hand, you breathe much slower when you are asleep. You must remember, of course, that your estimate will be only approximately correct because of these differences.

Why can this small boy use so many barrels of air?

Why We Breathe. We must think of the human body as any engine. Just as an automobile engine releases energy by burning fuel, so the human body likewise burns or oxidizes fuel to release the energy for daily work. But our work is done not in any one part of the body, but in the little units or cells which go to make it up. Evidently

then, if work is done in the cells, oxygen must get to all parts of the body in order to release energy there. To get oxygen there, it is first necessary to get it inside the body. Here is where the process of breathing comes in.

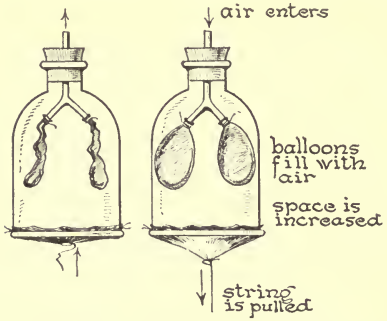
How Do We Breathe? Study carefully the diagram below. You will notice that the air passage leads from the mouth down into the chest, where it divides into two branches and finally breaks up into small branches which end in a mass of tiny air sacs in the lungs. The lungs are really spongy masses of air sacs and connecting tubes. The walls of these little clusters of sacs are lined with blood vessels, and when air passes into them from the outside when we take a breath, oxygen gets through these thin walls of the blood vessels into the blood. While this is happening, another gas, carbon dioxide, passes out from the blood into the air in the little sacs. Thus we see an exchange of gases takes place in the lungs. But this does not get the air into the cells; that is accounted for by the circulation of blood, which, as we shall see later, carries the oxygen to all parts of the body by means of the red corpuscles and unloads it where it will be used in the cells.



The breathing apparatus of man. Read the text and explain how and where oxygen might get into the blood.

Demonstration 5. To Show How We Breathe.

a. Take a bell jar, insert in the upper end a Y-shaped glass tube, and fasten over the lower ends of the Y two small rubber balloons. Over the lower open end of the jar tie a piece of sheet rubber. Pull on the rubber so that the cavity inside of the jar is made larger. What happens to the rubber balloons?



b. Allow the rubber to go back to its former position and press it upward into the jar. What happens to the balloons?

c. Cover the open tube in the cork with your finger and pull down the rubber as before. What happens?

Explanation. Try to explain from the movements you have observed why the rubber balloons fill with air when the sheet rubber is pulled down.

In the experiment let us suppose the rubber balloons represent the lungs, and the Y-tube corresponds to the air passages connecting the lungs with the mouth. We move our ribs outward when we take air into the lungs. This action is not shown in our experiment. At the same time we pull down a thin wall of muscle (called the diaphragm), which in the experiment is represented by the rubber sheet. This makes the chest cavity bigger and pressure of the air in the lungs becomes less than that of the atmosphere outside. The lungs fill with air, because it is pushed in by the greater pressure outside. The higher we raise the ribs, the more the diaphragm stretches and the larger the space in the chest cavity. So deep breathing brings in more air than ordinary shallow breathing does.

When the ribs go back into place, the diaphragm is curved upward into the chest cavity, which is thus made smaller. The air in the lungs is now under greater than

atmospheric pressure: in other words, the air is compressed and forced out of the lungs. The process by which the lungs are enlarged and air is taken into the lungs is called *inspiration;* and the process by which the lungs are compressed into smaller space, forcing out the air, is called *expiration.*

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

exhaled	air	compressed	pulled
inhaled	oxygen	upward	more
decreases	hydrogen	cells	greater
increases	water	tissues	less
liquid	curved	blood	pressure
dioxide	organs	lungs	lowering
atmospheric	carbon	atmosphere	pushed

Oxygen from the (1)____ enters the (2)____ in the (3)____ and is then sent to the (4)____ in every part of the body. Here it gives up (5)____, takes on (6)____ (7)____, and is returned to the (8)____ to be (9)____. (10)____ air has more carbon dioxide and less (11)____ than normal air. Muscular action expanding the ribs and (12)____ the diaphragm (13)____ the chest cavity, making the air pressure in the lungs (14)____. The greater (15)____ (16)____ outside forces air into the lungs. When we exhale, the air in the lungs is (17)____, and having (18)____ pressure than that of the outside (19)____, it is (20)____ out.

STORY TEST

Frank Explains Breathing

Read carefully and critically. List all the errors and suggest corrections.

The human lungs are the largest organs in the body. Together they hold $31\frac{1}{2}$ gallons. When we make the space in the lungs larger by lowering the diaphragm and expanding the ribs, air from outside is pushed in under greater than atmospheric pressure. Pressure on the air in the lungs is never more than 14.7 pounds

per square inch at sea level and decreases as one goes to the top of a high mountain. One breathes much easier on top of a very high mountain because the atmospheric pressure is less. In the lungs the blood takes oxygen and water vapor from the air. None of the nitrogen taken into the lungs is used by the body. The air sacs are those small cavities in which the air is never changed. One generally takes deeper breaths when awake than when asleep. The lungs become empty after making an expiration so that there is no air at all in the pleural cavity. This is why we gasp for breath after running a hard race.

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. These big ideas we call generalizations. For this unit they are as follows:

1. The gaseous envelope of the earth, called the atmosphere, extends upward for many miles, rapidly becoming less dense at high altitudes.
2. The air contains elements essential both to plants and animals.
3. Air can be removed from a closed vessel.
4. Atmospheric pressure is of great value to man.
5. The breathing and hence the life of many living things depend upon both the composition and the pressure of the air.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TESTS ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of the statements you believe to be incorrect. Your grade = right answers* $\times$ *2.*

I. **Air:** (1) fills " empty " glasses; (2) is dissolved in water of falling raindrops; (3) is a factor in winds; (4) is present in most soils; (5) brings us light and heat from the sun.

II. **The air is useful because it supplies us with:** (6) oxygen; (7) carbon; (8) hydrogen; (9) argon; (10) water for clouds.

III. **Exhaled breath contains some:** (11) oxygen; (12) nitrogen; (13) carbon dioxide; (14) water vapor; (15) sulphur dioxide.

IV. **Oxygen from the air is used in:** (16) rusting iron; (17) tarnishing silver; (18) fires; (19) electric lamps; (20) making a gas flame.

V. **The following assists one in taking air into the lungs:** (21) muscular action in chest wall; (22) the larynx; (23) the upward curving of the diaphragm; (24) atmospheric pressure; (25) the movement of blood through the tissues of the lungs.

VI. **The pressure of the atmosphere:** (26) depends upon the fact that air has weight; (27) can be measured with a thermometer; (28) will hold up a column of mercury nearly 34 feet high at sea level; (29) can be removed from a surface; (30) is greater at the top of a mountain than at sea level.

VII. **A vacuum:** (31) has only air in it; (32) does not contain any matter; (33) is useful in making the atmosphere do work; (34) is used to make balloons rise; (35) can be made by blowing all the air out of a bottle.

VIII. **Canned molasses and evaporated milk are easily poured out:** (36) from a hole in the center of the top of the can; (37) when two holes at opposite edges of the top are made; (38) from a single small hole near one edge of top; (39) from two small holes close together; (40) when the entire top of can is cut out.

IX. **Expiration in the process of breathing is:** (41) to stop breathing; (42) to die; (43) to exhale air; (44) to inhale air; (45) to force all air from the lungs.

X. **A vacuum can be made in a vessel by** (46) condensing steam in it; (47) filling with water to get rid of air and then pouring the water out; (48) pumping air into it; (49) blowing through a tube into a bottle; (50) by squeezing an atomizer bulb and then releasing it.

THOUGHT QUESTIONS

1. Oxygen, carbon dioxide, water vapor, nitrogen, and dust are constantly being taken from the air and they are constantly being returned to the air. Make a diagram to show the " cycles " of these substances; that is, show all the ways by which they are removed from the air.

2. John wishes to devise an apparatus to measure the air capacity of his lungs. How can he make it?
3. Gerald has his wind knocked out while playing football. What are his team mates likely to do for him? Is this the most effective remedy?
4. Find out and explain why it is so difficult to remove the glass cover on a jar of canned fruit.

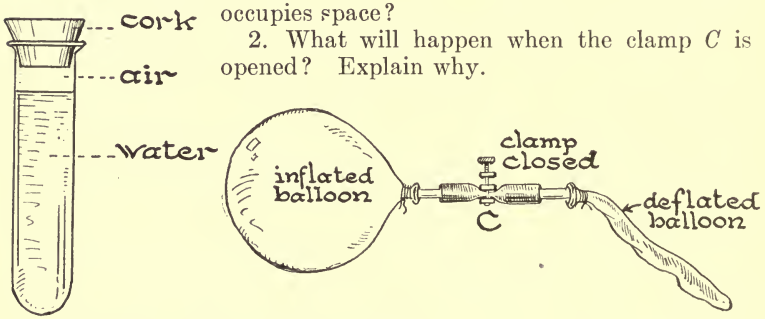
REPORTS UPON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. Galileo, an experimental scientist.
3. Trips made by man into the stratosphere.
4. Uses that boys and girls make of air.
5. Rare gases of the atmosphere.

SCIENCE RECREATION

1. If the tube is inverted, what evidence will indicate that air occupies space?

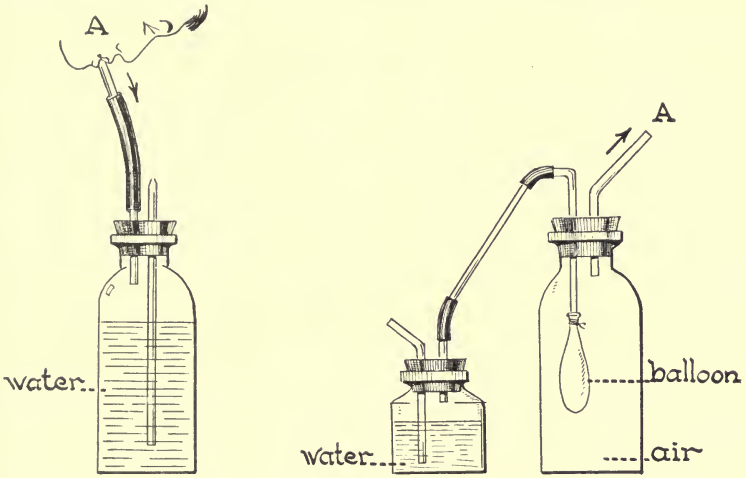
2. What will happen when the clamp *C* is opened? Explain why.



3. Make a Fountain-in-Vacuum

Procure an 8-oz. bottle, a 1-hole stopper to fit it, and a glass tube 12 inches long. Soften the glass tube in the middle in the flame. Draw it out to a fine thread. Break off the fine thread so there is only a small opening leading out of the glass tube. These tubes are called jet tubes. Wet one of the tubes and place it in the stopper, so that a jet end (small opening) will be inside. Never push a glass tube into a stopper when the stopper is in the bottle. Hold the bottle in a towel over the nose of a steaming teakettle for a few minutes. When the steam has driven the air out, cork

quickly and tightly. Immediately dip the glass tube into a glass of water. As the steam cools, what condition results in the bottle? Explain why the water rushes in and forms a fountain.



4. What will happen when *A* blows through the tube? Explain why.

5. What will happen if one sucks air from the large bottle through *A*? Explain reasons for two results which you can see.

6. Make a booklet of clippings, "Air and Its Uses." Use pictures and articles.

SCIENCE CLUB ACTIVITIES

1. Atmospheric Pressure and Vacuum Devices

Ask every club member to bring to the club meeting something which uses vacuum or atmospheric pressure, or both, in its operation. He should be expected to demonstrate or explain to the group just how his device works.

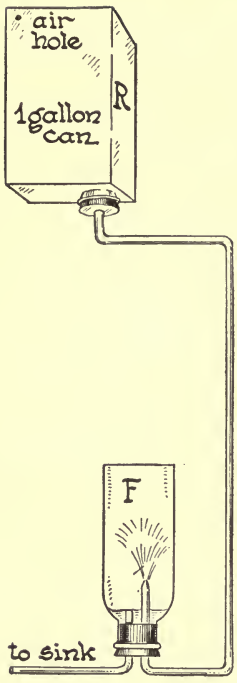
2. Galileo and Torricelli

Reports on the scientific works of these early scientists.

3. Fountains: A Good Way to Make a Fountain

A. *Gravity Pressure*

The tin can has a tight-fitting stopper with a tube passing through it. This is joined by a rubber tube to the jet tube in the glass



bottle. A hole is punched through the can near the bottom to allow air to enter the fountain. Water may run out. The higher the reservoir is placed above *F*, the greater the force in the fountain.

4. Exploring in the Upper Atmosphere

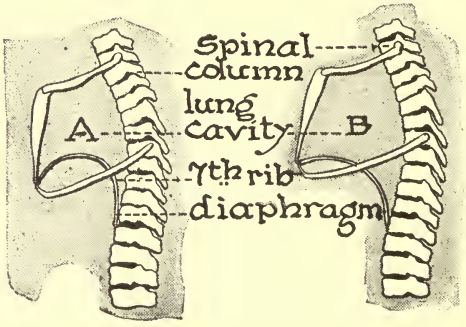
Read up on this topic in books and periodicals. Find out what people have explored the atmosphere higher than the highest point of land and how they have done it. What do they expect to achieve by these adventures? What are the dangers? Have different members of the science club report upon different achievements.

5. How to Show the Crushing Power of the Atmosphere

Use an empty gallon oil or sirup can which has a small opening that can easily be closed air tight with a cork. Put about one half inch of water in it. Place it over a fire, and boil the water. When the steam has driven out all the air (two minutes of boiling), shut off the gas and put the stopper in air tight. Place the can in the sink and pour cold water upon it. Do you understand the reasons for the result? How many square inches of surface has the can? What is the pressure of the atmosphere on 1 sq. in.? On the total surface?

6. How to Show the Changes That Take Place in the Chest Cavity When We Breathe

Have some member of the club make a large chart of the diagram shown on this page and a large model of the mechanical device shown on the opposite page. Have the club members study the chart carefully and then have the demonstrator work the model while asking the following questions:



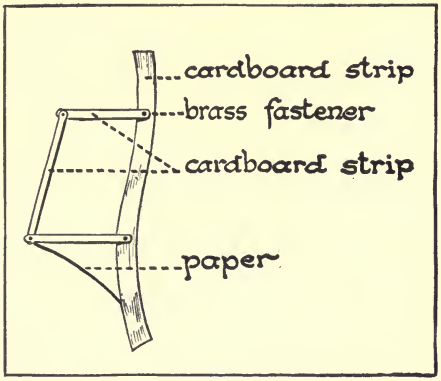
(1) What happens to the human diaphragm when the ribs are raised?

(2) What happens to the human diaphragm when the ribs are lowered?

(3) What causes air to come into the lungs?

(4) What causes air to pass out of the lungs?

The chart and apparatus should be presented to the science department of the school for class use after the meeting. It will be valuable for class demonstrations.



7. How to Make a Battery Jar from a Bottle

Cut the top off a large glass bottle or jar — one quart or one gallon — the larger better. Make a deep file scratch where you wish to cut it. Heat a heavy metal — soldering iron or curling tongs — red hot and press upon the scratched glass. After a crack is started, keep applying the red hot metal just a little ahead of the crack and it will follow it around. Another method is to wet a cotton string with kerosene. Wind two or three layers around the bottle and tie. Set fire to the string, holding the bottle horizontally and turning slowly. When fire goes out, wet the bottle. This jar will be very useful in many experiments.

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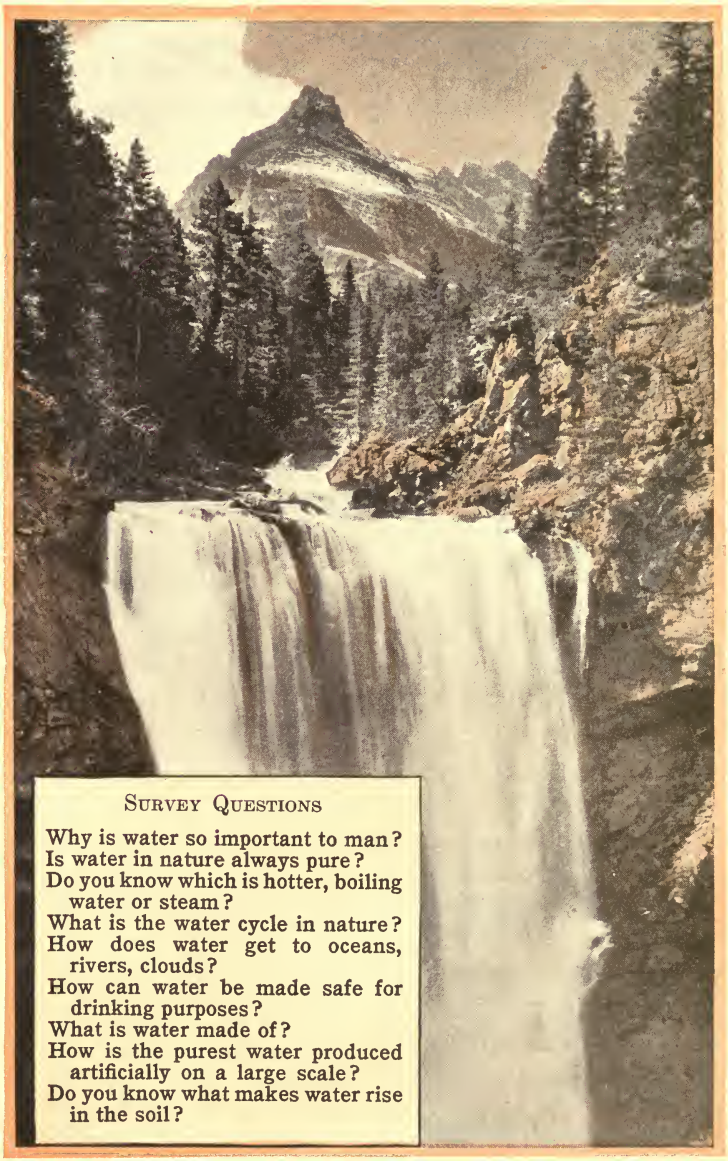


Survey Questions

Why is water so important to man?
Is water in nature always pure?
Do you know which is hotter, boiling water or steam?
What is the water cycle in nature?
How does water get to oceans, rivers, clouds?
How can water be made safe for drinking purposes?
What is water made of?
How is the purest water produced artificially on a large scale?
Do you know what makes water rise in the soil?

Dawn Mist Falls. *Photo by Hileman*

UNIT IV

WATER AND ITS EVERYDAY USES

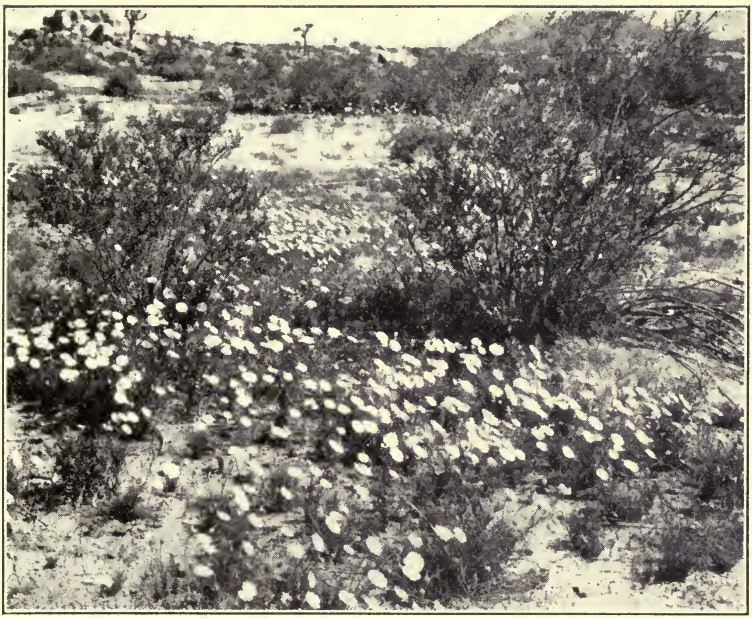
PREVIEW

Did you ever think what the world would be like without water? There could be no rainy days, no snow storms, no coasting or skating, no bathing, swimming, or sailing, and no water to drink. Without water there could be no plants, hence no vegetables or fruits, no animals and no food for man. You can readily see that without water on the earth there could be no life, not even man. The nearest thing to a waterless earth is found in the desert, but even in this parched and dry area there may be a few springs or pools of water left after a desert storm. Mile after mile of shifting sand, no plants except an occasional cactus, and a few dried-up bushes; perhaps a snake, a lizard, or a desert mouse, and once in a while a bird is all the life that we see. But visit this same spot after the spring rains have swept down from the mountains, and we find the whole desert floor covered, as if by magic, with little plants having many bright-colored, red, magenta, blue, and violet blossoms. Even the dried-up desert bushes have put on leaves and are in flower. All these changes have come because of the temporary presence of water. Some deserts, such as the Sahara, however, are so unfavorably situated that they do not receive enough water to sustain life at any time of year. Such places are a barren wilderness and sometimes so extensive that it is with great hazard that man attempts to cross them.

The desert in California before the rainy season. Note the dry sandy foreground.

Water is one of the most important factors of our environment. While there are some living things like earthworms and some fish that can get on without light, and while there are some animals and plants that can live in a very low or a very high temperature, none of them can get on without water. We even know of some plants that can live without air, but these plants, tiny bacteria, get oxygen from their foods and must have water in order to grow. Living things need water because they are largely composed of this substance.

Pure water is one of man's most desired possessions. It comes from the clouds and after a long or short stay with us goes back again. The adventure of a drop of water would make an interesting story. Dropped from the clouds as rain, it might fall into a river and from there pass into a large body of water, where it would stay until

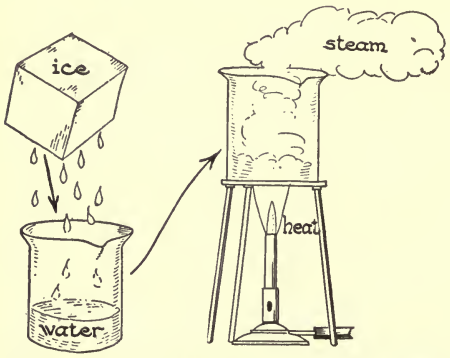


The same spot after the winter rains. Compare the trees in the background in both pictures and you will see the photographs are taken at the same place. How do you account for the difference?

the hot sun caused it to evaporate into vapor and pass again into the clouds. Its next trip might take it to a forest, where it would fall into the ground, remain there for a time, be absorbed by the roots of the tree, and pass up through the stem to the leaves, where perhaps it could be used by the green leaves of the tree in the manufacture of food. Or perhaps it might be evaporated through the holes in the leaf as the tree made food in the sunlight. Again in the air it might be condensed as dew and then get into the soil again. Eventually, however, our drop of water would become a part of the vapor of the air, would become condensed, and again come back to the earth as rain, or snow, or hail. This continual round of water is known as the water cycle.

PROBLEM I. WHAT IS WATER?

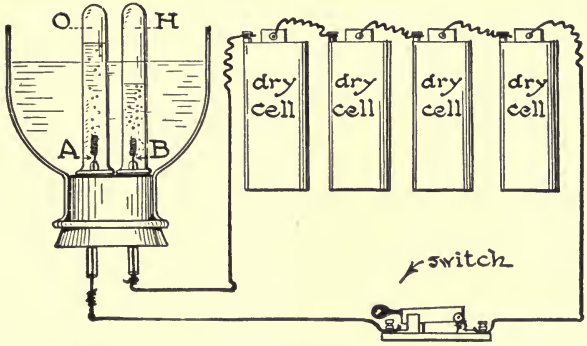
Those of you who live where snow falls in winter have had the experience of a cold rain changing first to sleet and then to snow. You have at some time brought ice and snow into the house and seen it change back to water. Perhaps you have placed it in a vessel over the fire and watched it pass off into the air as steam. You have all seen water in the three states — solid, liquid, and gas. But in all of these conditions, its molecules are still made up of the same elements.



What kind of changes are taking place here? How do you know?

How Scientists Found Out the Composition of Water. Water is so common it seems absurd at first to ask, "What is water?" And yet if any one asked you the question, what would you answer? Is water an element? Is it a compound? Does it contain several things mixed together? The chemist has at his command several methods by which he can solve such a problem as this. As long ago as 1784, Henry Cavendish burned hydrogen in oxygen and produced a liquid. This liquid he found had all the properties of water and in fact was water. Sixteen years later, two chemists, Nicholson and Carlisle, reversed the process of Cavendish. They began with water, and by using electrical energy tore the molecules apart and produced hydrogen and oxygen. This process is reproduced now in thousands of schoolrooms every year. The process is called *electrolysis of water* and is

carried out as follows: The jar has two coils or plates of platinum (*A* and *B*) extending upward into some water which has been made acid by having about a tablespoonful of strong sulphuric acid added to half a pint of water. The test tubes are each filled with this water



Electrolysis of water. What does this experiment show about the composition of water?

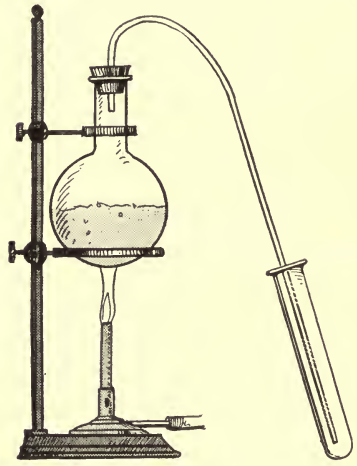
and placed over the platinum wires. The acid is used to make the water conduct the electric current. When the current from four dry cells is sent through the water, small bubbles rise from the platinum wires and collect in the tops of the tubes. One gas forms twice as fast as the other. If this gas is removed and lighted, it burns or pops with a slight explosion. This gas has been proved by experiment to be the element hydrogen. When the other tube of gas is tested with the glowing end of a splint, it causes the splint to burst into flame. The gas is the element oxygen. These two elements have come from the water because the chemist finds that there is the same quantity of sulphuric acid left as he used at the beginning. We may now conclude that pure water is a compound made up of hydrogen (2 parts) and oxygen (1 part). This is expressed in the familiar formula H_2O.

What Is Pure Water? Water in its purest natural state is rain water. It comes from the clouds, where it is

made from pure water vapor which was condensed high in the air, therefore having little opportunity to get any impurities into it. We can make any water pure by distilling it, because this process forms water in much the same way that it is made in the clouds.

Demonstration 1. To Show How Water May Be Purified.

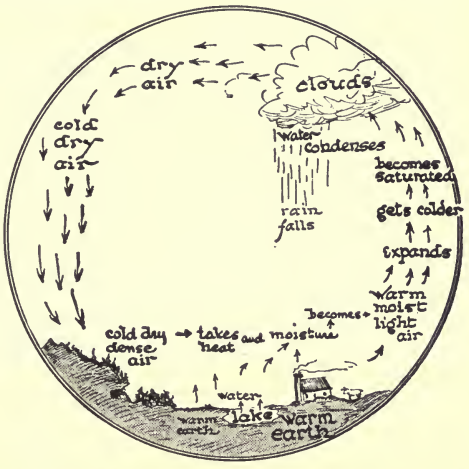
Place a Florence flask on a ring stand, and bend a tube as shown in the illustration. Pass it through a perforated cork which will fit in the mouth of the flask. Fill the flask half full of water colored with red ink and add one teaspoonful of salt and two of sugar. Place a lighted Bunsen burner under the flask and put a test tube at the lower end of the tube. Allow the tube to stand in cold water to keep it cool.



Observation. Soon after the water boils, notice what happens. Where do the drops of water appear? Why do they appear more frequently here? What is the color of the water in the test tube? Taste it. Result? What substances put into the flask do you find in the test tube? This process of obtaining water is called distillation. How does distillation purify water?

Distillation. Distillation of water is very important. It involves two distinct processes: *vaporization,* in which the water is changed to steam, and *condensation,* in which the steam is changed back to water. Natural waters, which contain some impurities, if put into the storage battery of the automobile would soon ruin the battery. When large quantities of artificial ice are made, unless the water is very pure it is first distilled before freezing. When a large can of dirty water is freezing, the impurities separate and move to the center of the can where the water is frozen last.

What Is Evaporation? When ice is left in a hot kitchen uncovered, it absorbs heat and soon changes its state from solid to liquid, and if it is left exposed to the air for a short time, some of it will pass off into the air. Evaporation is the changing of water to a gas when the change is at the surface of the liquid. Some water evaporates into the air whenever air and water are in contact. The warmer it is, the faster it evaporates.



Read the text and then explain this diagram of the water cycle.

The Water Cycle in Nature. Air, soil, and living things play an important part in the ceaseless changes of water on our earth. The atmosphere receives water in the form of water vapor and gives it back in a variety of ways. Evaporation of water from all surface bodies of water, from wet rocks and soil, and even from snow and ice charge the air with moisture. To this must be added the moisture given off from the burning of fuels, by the breathing of animals, and from trees and other plants. A single tree sometimes gives off almost half a ton of water in a day. This water vapor in the air is an invisible gas. When air that has become saturated with moisture is cooled, some of the water separates out into minute particles. Continued cooling increases the size of the particles. The particles may make dew drops, fog, clouds, and rain, or if the temperature is very low, frost or snow will result. The great bulk of this condensed

Galloway

Is the sun really drawing water? Explain the picture after reading the text.

water will come back to the earth from the atmosphere in the form of snow and rain. This return of the water makes the earth moist; fills the rivers and ponds; and supplies animals and plants with the necessary water. Evaporation then starts another cycle and the process is continued. Thus there is on the earth a never-ending cycle of water from solid or liquid to gas and back again from gas to liquid or solid. This is the water cycle in nature.

Sometimes there are many tiny particles of moisture in the air. They are too few to form a cloud but sufficient to reflect and show rays of sunlight. This phenomenon is responsible for the saying, "The sun is drawing water." Clouds at a higher level often have "holes" in them and sunshine passes through. If small particles of water or dust are in the air lower down, the beams of light become visible just as they do when shining into a dark attic or barn chamber through a knot hole or other small opening.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

nitrogen	evaporation	impure	mixture
composition	boiling	cheap	electrons
compound	union	hydrogen	oxygen
elements	twice	oxygen	separated
rain	costly	water	method
pure	molecules	gas	solution
purifying	distillation	distilled	stream

Water is a (1)____ formed by the (2)____ of the elements (3)____ and (4)____. When water is separated into its (5)____, it is found that there is (6)____ as much hydrogen as (7)____. When solids are dissolved in water, the water can be (8)____ from them if heat is applied. Heat causes some of the (9)____ of pure water to change to a (10)____ which leaves the (11)____. This process of (12)____ a liquid is called (13)____. The purest water that we make artificially is (14)____ water. When hydrogen burns (15)____. results which is also (16)____, but this (17)____ of producing (18)____ would be very (19)____. When distilled water is not available, the next purest water we can get is (20)____ water.

STORY TEST

Catherine Reports on "What Is Water?"

Read carefully and critically. List all the errors and suggest corrections.

It seems almost too commonplace to tell you what water is. How can one ever be in doubt? A glass of milk is white, ginger ale is amber and has bubbles in it, sulphuric acid is very heavy, and gasoline has an odor. If I can see, lift, and smell a liquid in a glass, I can tell if it is water. Some may say a glass of lye (caustic soda in water) or potassium cyanide solution would look the same as water and could not easily be told by weight or odor. Even if this is true, you could tell the difference after you drank them, so what does it matter? The chemist tells us that water is made of hydrogen and nitrogen and that the amount of hydrogen is double that of the other compound. When water is boiled, it goes off in two separate gases, one of which will burn. Natural water is always pure water, but the artificial water made by vaporization and condensation is almost always impure. We have read a lot about heavy water recently. That is water that has lead in it.

PROBLEM II. WHAT USES DO WE MAKE OF WATER?

Uses of Water. If you were to make a list of all the ways in which you use water, you would doubtless think of its first uses in the morning for washing your body, cleaning the teeth, and then drinking at breakfast. Keeping clean is certainly important. If a Roman Emperor wished to become popular with his people, he caused a bathhouse to be built. The Romans took their bathing seriously. They had magnificent bathhouses with hot and cold showers or tubs, and the wealthy Roman lounged away a good part of the day enjoying the various steps of his complicated bath. It was the place where a Roman gentleman sat and gossiped and swapped the day's news, for there were no newspapers. They knew the value of a clean skin, and knew the feeling of exhilaration that came from a cold bath following a warm one.

A Roman bath in Bath, England. When the Romans invaded England they built baths like the ones they had in Rome.

Why Keep Clean? There are two reasons why we should keep ourselves and our clothing clean. First because we wish to be decent and attractive to others, and second because good health demands that we keep our clothing and bodies free from dirt and germs.

What Makes Water So Useful? The uses of any kind of matter are determined very largely by its properties. Water is no exception. The form in which water exists, whether solid, liquid, or gas, determines some of its uses. We cannot wash clothes in ice nor can we skate on steam. What do you suppose makes water sometimes liquid, sometimes solid, and at other times a gas? After a little thought you will say correctly that heat determines the state in which water exists.

In general it is true that the warmer the water the more solid the water can dissolve, but at any given temperature there is a limit to the amount that it can hold. When water has dissolved all that it can at a given temperature it is said to be saturated. If a saturated solution is cooled or if it loses water by evaporation some of the dissolved solid will separate from solution. With gases the temperature effect is just the reverse. The warmer the water the less gas it can hold in solution. Boiling the water will remove all gases which are in solution.

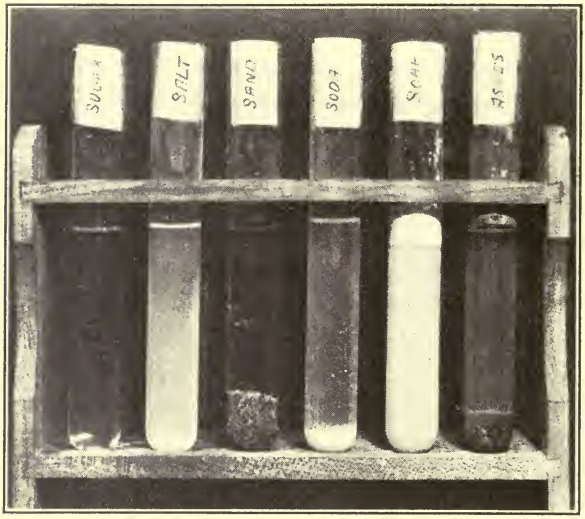
Demonstration 2. Water as a Solvent.

Arrange six test tubes half full of water in a test-tube rack. Add a gram of each of the following substances, each one in a separate tube: (1) salt; (2) sugar; (3) oil or grease; (4) charcoal or ashes; (5) soap chips; (6) baking soda. Shake to see if each substance will dissolve in the water. Tabulate the results.

Practical Application. Why will water clean some dirt spots more readily than it will others?

When a small portion of salt or sugar is put into water and stirred, the salt or sugar disappears. Water has dissolved the solid. Neither an iron nail nor a silver

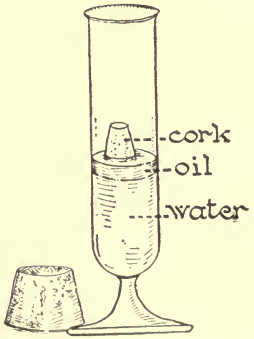
spoon will dissolve in water. Water has the property of dissolving some substances which are called soluble;



Wright Pierce

Try an experiment like this and see what results you get.

those substances which will not dissolve are insoluble. A liquid which will dissolve a substance is called a *solvent* of that substance. Every part of a breakfast cereal can be salted evenly if the salt is dissolved in the water before the cereal is added to the water.



Make a new diagram for your workbook to show result after adding soap and shaking.

How to Make Oil and Water Mix. You often hear the saying that "water and oil do not mix." You can prove it if you wish and then you can disprove it. Suppose you put half a cup of water into an 8-oz. bottle and add a tablespoonful of kerosene or fuel oil to it. Close the bottle and shake it vigorously. Upon standing, the oil quickly

separates. You have proved that water and oil under ordinary conditions do not mix. Now start again, but put a few shavings of soap in the water. Shake to make a soapy solution. Add the oil and shake vigorously as before. This time the oil does not separate from the water. Shaking divides the oil into many exceedingly fine droplets. In water alone they quickly combine and separate out from the water, but when coated with soap which is in the water, they keep their finely divided state and remain mixed with the water for a very long time. Thus you have shown that when soap is present to lend its aid, water and oil will mix. This mixture is different from solution and is called an *emulsion*. A kerosene emulsion is an insect spray used to kill aphids. Milk is an emulsion. It has oil in the form of butter fat distributed in very fine particles. These rise very slowly, and when they form a layer on top of the milk, they are known as cream.

Value of Soap in Cleaning. It is largely the grease and oils that hold the dirt particles to the hands and clothing. Water alone has little cleaning value because it cannot remove the oil. But when soap is added to the water it forms an emulsion with it and this loosens the dirt. For this reason soap is a valuable cleaning aid. When one lives where the water is hard, containing minerals like calcium compounds in the water, the soap is destroyed. Such water must be softened sometimes by boiling, sometimes by adding washing powder or other chemicals before using soap. Otherwise a great deal of soap will be wasted.

Why We Need Water. Do you know that your body is over 65 per cent water, and that some animals such as the jellyfish are 99 per cent water? Have you thought that the plants we eat, stems like celery, roots like radishes, all contain a large per cent of water, and that

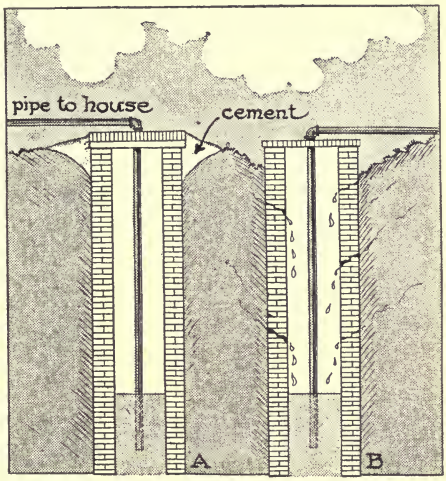
most foods, even though they seem dry, contain quite a good deal of water? Our doctors tell us we should drink from six to eight glasses of water a day, some of which may be taken in the form of milk. We can see a reason for this now that we know that all foods and our own body contain so much water. Water is also used not only to carry foods from one part of the body to another, for foods have to be dissolved in the blood before

Do all living things contain water? Mention something that does not.

they can be used, but it is used in the growth and repair of the cells of our body. If we examine a young growing shoot of a plant, we will find that the rapidly growing part is much softer and juicier than the older parts. This is because it contains more water. Not only is water used in the body to transfer foods, but it is also necessary to get rid of wastes. Some of the most poisonous body wastes are passed off in the urine and in perspiration.

How We May Make Water Safe for Drinking. Many of us have visited friends in the country and remember with pleasure the cold water from the wells or springs near their homes. But a glance at the picture will show

that such water might be very unsafe. If water is taken from a well, the well should be protected by a cap of cement, as shown in the diagram, and it should be so located that drainage cannot enter it. Well water should be tested frequently for germs by town or state Boards of Health. A well in ordinary sandy soil situated above and at least 100 feet from any cesspool is safe.

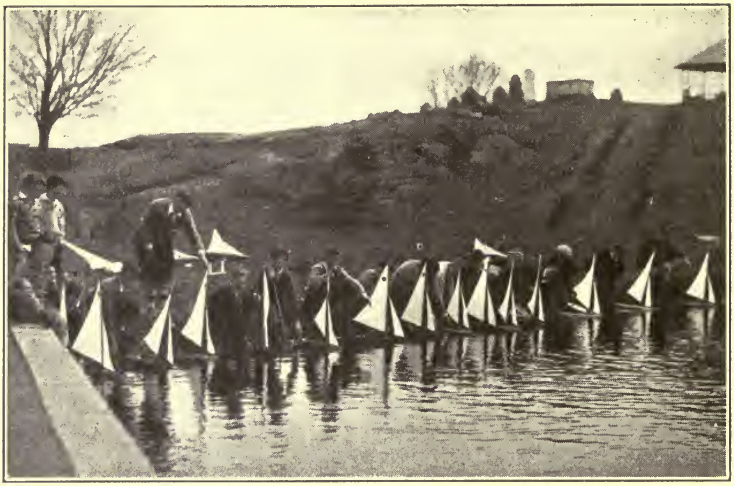


Compare the conditions of these two wells. Under what conditions might the water in *B* be safe? When unsafe?

You may go camping and be in doubt about the safety of your water supply. Boiling it for 20 minutes will kill practically all harmful germs and will make it safe for drinking. Unfortunately, boiling drives off the free oxygen and gives it a flat and unpleasant taste. The oxygen can be put back into the water by violently shaking it for a short time in a bottle partly full of air.

Water Used in Cooking. Water is also used to cook foods in. We make our bread by mixing flour with water to form dough. We make our tea and coffee because of the solvent action of water which extracts the flavor from the tea leaves or the ground coffee so that the liquid has the flavor instead of the original tea and coffee. We can also transfer heat by means of water or steam, as you see when you cook a cereal in a double boiler.

Other Uses of Water. We have seen that both plants and animals are made up very largely of water. This



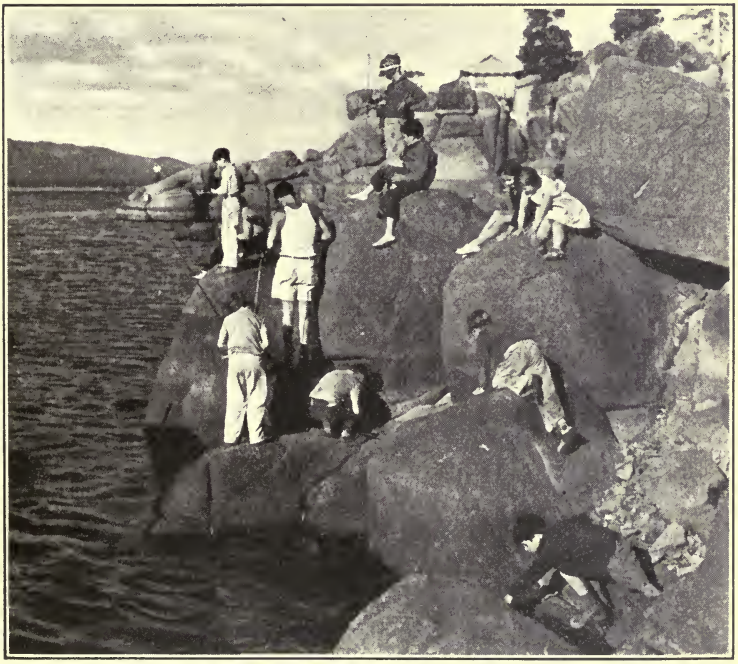
A miniature yacht race. Do you know how to sail a boat into the wind?

accounts for the fact that our gardens, lawns, and plants kept in the house need constant watering. We know that they wilt when they do not have sufficient water. Moisture evaporates from bodies of water into the air. We have all had the experience of sitting in the draft of an electric fan in order to cool off. Nature adds moisture to the air in a large way when breezes blow over large bodies of water, or when great forests send off into the air large amounts of moisture. Water helps us to keep more comfortable, and communities near large bodies of water have usually a pleasanter climate than those far away from sources of water. Finally, water is used in our recreation. Every boy and girl ought to know how to swim and sail a boat. Rowing, canoeing, and fishing are all recreations that depend upon water.

Life in the Ocean. In addition to all the other uses of water, we can add perhaps the most important of all, the fact that water is the home of vast numbers of living things. Think of the amount of the earth's surface

covered by water — three fourths of it. Think of the thousands of forms of fish life that dwell in our oceans. Go to a museum and see the groups showing underwater life — sponges, corals, sea anemones, jellyfish, sea fans, and sea feathers, hundreds of kinds of worms — flat, round, or jointed. And besides these there are millions of tiny one-celled animals, sometimes so plentiful that although microscopic in size, they give color to the ocean and furnish food for hundreds of kinds of bigger animals.

Variety of Life in Ponds. In addition to the larger bodies of water our brooks and ponds swarm with life, both plant and animal. All kinds of life may be found there. Frogs, turtles, salamanders, and snakes are in



Wright Pierce

Have you ever gone fishing? There are bass and trout in this lake. What else do you think you could find on the shores or in the water?

the water or on the banks, while snails, mussels, clams, slugs, and worms of various kinds may be found on the mud of the bottom. Then there are fresh-water sponges which look like plants; little green or gray hydras, and thousands of tiny water fleas which form the food of fish and other inhabitants of the pond. It is true that there are many animals which can live in water or in air, but many of these begin their life in water. Mosquitoes, flies, and dragon flies live in water in the earlier stages of their existence, emerging into the air only for their adult life. The mud at the bottom of the pond will disclose numerous insect larvae. The surface film, the water, and the muddy bottom will all reveal interesting forms of life. Over 70 different forms of life have been found in one eighth of a cubic inch of water when examined with a compound microscope. The water is more densely inhabited than the air or the land.

American Museum of Natural History

This is a glimpse of pond life as seen under a magnifying glass. Can you name any of the things you see in the glass?

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

salt	bluing	solution	56	steam	acid
liquid	solid	ice	boil	gas	boiling
solvent	dissolve	form	heat	evaporation	fuels
mix	soap	emulsion	mixture	washing	dissolves
oils	water	boiling	oil	65	freezing

Water is ordinarily a (1)____, but in very cold regions it is a (2)____ called (3)____. When heated strongly on the stove, water will (4)____, but if left in the open air, it changes to a (5)____ in the process of (6)____. When salt is stirred in water, it disappears because water is an excellent (7)____. Water will not (8)____ insoluble substances. The (9)____ or condition of water is determined by the amount of (10)____ it contains. Oils which do not readily (11)____ with water are made to do so by the addition of (12)____. The result is called an (13)____. In the process of cleaning, water is aided greatly by the addition of (14)____. Much of the dirt we try to remove in the process of (15)____ is held by fats or grease or (16)____. Soap in (17)____ forms an (18)____ with the fat or (19)____ and so loosens the dirt. People need to drink much water because it helps carry foods and remove waste and because the body itself is (20)____ per cent water.

STORY TEST

Alton Relates His Experiences on Solubility

Read carefully and critically. List all the errors and suggest corrections.

I will tell you of my experiment on testing solubility of substances in water which I did at home. I found that water will dissolve salt and "absorbent" cotton. I presume this kind of cotton is called "absorbent" because the water absorbs it and makes a solution of it. Water will not dissolve ashes or soap chips. I found that oil would not dissolve in water alone, but if I put soap in the water with the oil and shook or stirred vigorously, the oil did not separate. This is because it had dissolved in the water. I boiled some water from a deep well until the water disappeared; a small amount of solid was left. I put coffee grounds into water and boiled it. I poured the liquid off and the grounds were left, therefore there is no solution formed when one "makes coffee."

One reason you do not notice the adulteration of sugar with sand is that the particles look alike and they are all completely dissolved in water.

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. These big ideas we call generalizations. For this unit they are as follows:

1. Water in all its three states, solid, liquid, and gas, produces important changes on the earth.
2. Water is a compound that can be separated into its elements.
3. Through a variety of changes in state, water passes through a cycle in nature.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of the statements you believe to be incorrect. Your grade = right answers* $\times 3\frac{1}{3}$.

I. **The air receives water from:** (1) the ocean; (2) breathing animals; (3) condensation of moisture; (4) living plants; (5) deep-sea fish.

II. **When common salt is dropped slowly into boiling water:** (6) it forms crystals on the bottom of the dish; (7) a solution results; (8) an emulsion is formed; (9) the water becomes a solvent; (10) the salt is a solvent.

III. **Water is a compound whose molecules are composed of:** (11) two atoms of hydrogen; (12) like atoms; (13) oxygen and

nitrogen; (14) two electrons and one proton; (15) one part oxygen and two parts hydrogen.

IV. **In the process of making distilled water:** (16) two changes of state are required; (17) a source of heat is required; (18) a source of cold is required to remove heat; (19) pure water must be used to start with; (20) sea water cannot be used.

V. **A water is safe to drink if it has been:** (21) formed by melting glacier ice; (22) freshly distilled; (23) filtered through five layers of cloth; (24) taken from a river; (25) boiled 20 minutes.

VI. **Living things in water:** (26) may be more numerous than in an equal sized volume of land; (27) are all microscopic in size; (28) are all animals, no plants being found there; (29) often only pass part of their lives there; (30) all have to come to the surface to breathe as there is no oxygen in the water.

THOUGHT QUESTIONS

1. Why will water clean some dirt spots better than others?
2. What is a solvent? Find the names of three solvents and name one important use of each.
3. Does milk hold cream in solution? What makes cream rise?
4. If hydrogen will burn in the presence of oxygen, why doesn't the hydrogen burn in water when water is composed of one atom of oxygen and two atoms of hydrogen?

REPORTS UPON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

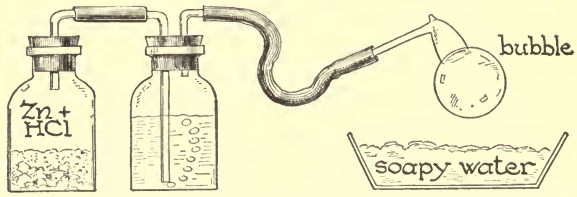
1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. The waters of the earth.
3. Trips made by man down into the ocean.
4. Uses boys and girls make of water.
5. Water: in and out of the air.

SCIENCE RECREATION

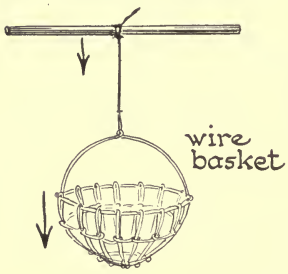
1. Make Hydrogen Balloons

Prepare hydrogen gas from dilute hydrochloric acid by action on zinc scraps. Carry the gas through water to wash it. The hydrogen is discharged from the end of a fire polished glass tube

or a clay pipe. Dip the end of the glass tube into the soap solution. Remove quickly. When the bubble is an inch or two in diameter,



shake it off and watch its movement. Do not have any flame near the hydrogen generator. When mixed with air, hydrogen will explode violently upon the application of a flame.



2. Make Distilled Water

Devise an apparatus using things you have at home and make distilled water for the automobile battery.

3. Crystal Making

Make crystals by allowing saturated solutions of salts to evaporate slowly. Suspend strings in the liquid for the crystals to cling to. They will also form on the vessel holding the solution. Salts that are good for this are: common table salt, alum, potassium dichromate, and copper sulphate. If you start with a hot saturated solution, crystals will start to form as the solution cools. Make a basket form of cotton-insulated wire #20. Suspend this in a hot saturated solution of potassium dichromate. A beautiful crystal ornament will be produced by allowing crystals to grow upon this for 24 hours.

SCIENCE CLUB ACTIVITIES

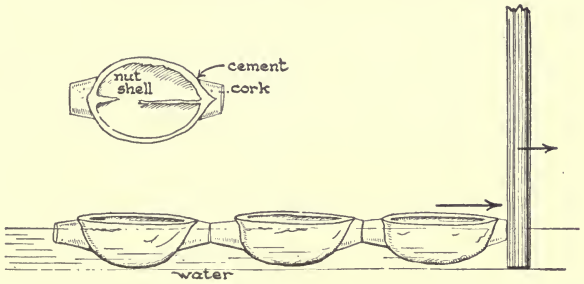
1. Toy River Barges

Materials needed: Three half walnut shells; three small cork stoppers; stick of wood about size of pencil; paraffin.

Preparation: Cut the corks into halves and fasten them with paraffin to the ends of the shells so that there will be a smooth

vertical surface when the shells float in water. Have the top of the cork come just level with the top of the shells. Liquid solder may be used in place of paraffin.

There is a film over the surface of water like stretched rubber. The force of this film on water is great enough to hold the toy river



barges together if they are brought end to end. The whole line of them can be drawn along by holding one end of the stick in the water just in front of one and pulling slowly.

By pinning a small piece of soap to one end of the stick and holding that in the water just back of the boat, you can apparently repel a single boat. The soap weakens the surface film so that the boat is pulled in the opposite direction by the film on the other side of the boat. By using soap on one end to repel and the opposite end to attract, you can make the boats maneuver in a manner which appears mysterious to one who does not know the secret.

2. Pond Life Aquarium

Procure several large glass jars. Have the club members divide into several groups and visit different small pools and ponds on a field trip. Bring back both plant and animal specimens. Arrange several aquariums and watch development in them.

3. Prepare a Scrapbook on Water

Classify the uses of water under: solid, liquid, and gaseous form. Each member report upon the uses. A contest may be arranged by dividing into three groups, the *ice* group, the *water* group, and the *steam* group. An important use named wins a point.

REFERENCE READING

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Meister, M., *Water and Air.* Scribners, 1930.
Thompson, J. M., *Water Wonders Every Child Should Know.* Grosset.
Whitman, W. G., *Household Physics.* Wiley, 1932.

Survey Questions

Does all fire produce heat and all heat produce fire?
What must be done to set a combustible substance on fire?
Why does a fire sometimes go out by itself?
What is our greatest natural source of heat?
Do you know how heat travels from one place to another?
Do you know the scientific difference between heat and cold?
What instrument measures temperature and how does this instrument work?

Galloway

UNIT V

HOW WE USE HEAT

PREVIEW

Have you ever thought how important a part heat plays in your life? Ancient peoples, Babylonians, Aztecs, and our American Indians, worshiped the sun because it gave them heat and warmth in winter and provided for their crops in summer. Probably fire has been more worshiped than any other element in nature. The use of fire must have been a great discovery to ancient people. Nobody knows how man first got it. The first fire may have come from lightning striking a tree, it may have come from a chance focusing of the sun's rays through a rounded quartz pebble, it may have come from an eruption of hot lava from a volcano, it may even have come as the boy

The artist has shown some primitive people worshiping fire. What do you know about fire worshipers? From a mural in the Library of Congress.

Wright Pierce

Is this girl scout going to make a fire correctly? Could you do better? If so, how would you go to work?

scouts make it today, from friction by means of rubbing things together, or it may have come from a chance striking of two hard stones so as to make a spark. But with it came comfort. Think of what home would be without any heating apparatus, or without fire to cook with. Think of the fun you have popping corn or making candy, or getting warm around a bonfire. Think of how heat is used in melting substances such as solder, and how it can be used for casting lead toys. These are only a few of the cases in which we use heat. Our uses of heat depend upon our ability to control it. To control it we must learn how it acts. Heat can make things larger, can make gases from liquids and solids, and can change the flavor of foods. Heat can be transported by water or steam from a furnace in the cellar to our rooms, where

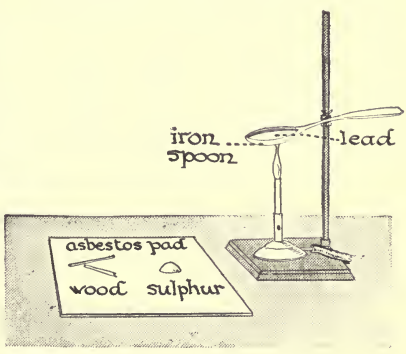
it gives us warmth and comfort. It means warm rooms in winter; it makes possible the cooking of raw foods; it gives us hot water, hot air, and hot foods. Today fire has come to be used in hundreds of ways that the ancients never dreamed of.

PROBLEM I. HOW IS HEAT PRODUCED?

If you are a boy or girl scout, you know how to build a fire. First you get some paper or dry leaves, cover with some shavings or thin kindlings, and then place larger sticks at an angle over the other materials so as to make a good circulation of air. When the fire has started, you fan it or blow on it to keep it burning. Evidently a fire must have something that will burn, a good supply of air which contains oxygen, and enough heat to warm the material to what is called its *kindling temperature.*

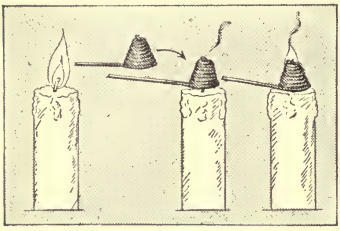
Demonstration 1. Kindling Temperatures.

Break off and discard the heads of two matches, place the sticks on an asbestos mat. Two inches away from them put a piece of sulphur or brimstone the size of a grain of rice. Melt about 20 grams of lead in an iron spoon supported on a stand as shown in the diagram. Do not use more heat than is needed just barely to melt the lead. When the lead melts, pour half of it on the asbestos so that it touches the sulphur, and pour the rest of it so that it covers the end of the sticks. Does either substance take fire? Remelt the lead in the spoon. When it is just melted, turn the gas under it low and stick the end of a match stem into the lead. Does it take fire? Rub the end of one of the sticks in the sulphur so that some of it clings to the stick, and touch it to the lead. Look closely, for sulphur burns with a pale blue flame. Which has the lower kindling point, the sulphur or the wood?



Kindling Temperature. This shows that different substances take fire at different intensities of heat. The intensity or degree of heat is called *temperature*. In making matches, the match head contains a compound of phosphorus which ignites at a very low temperature, and a compound that gives off oxygen easily, also powdered glass or sand, and glue. By rubbing the match head against a rough surface, enough heat is developed to ignite the phosphorus. In the safety match, the head is made of a substance which burns at a low temperature, while red phosphorus mixed with sand or powdered glass is placed on the box to give it a rubbing surface. The head of the match will not ignite unless it is helped by the phosphorus on the box.

What Causes Fire? Many substances like phosphorus, sulphur, and wood when heated to their respective kindling temperatures in the presence of air or oxygen will burn and produce fire. Such materials if burned to give useful heat are called fuels. As we shall see later, gas, coal, oil, and wood are fuels. When fuels burn, heat is produced by oxidation. In order to keep a fire burning, we must have oxygen and keep the temperature at or above the kindling temperature. You can easily show the effect of cooling below the kindling temperature. Copper is a good conductor of heat. Wind a piece of copper wire into a spiral coil $\frac{1}{3}$ of an inch in height, making it large enough to slip easily over the wick of a candle. Light the candle and bring the cold wire down on the wick, the light will go out. But if you light the candle again, then heat the copper coil to red heat and bring it down over the wick, the candle will continue to burn. This shows us that to



Why does the flame go out?

keep a fire burning we must not cool it too much. Heat is transferred to the cold copper wire. This transfer of heat from one place to another and from one body to another will be discussed in our next problem.

The Use of Tinder in Colonial Days. In colonial days they caught sparks in tinder and produced fire in a much more uncertain way than we do with our modern matches. If you wish to make tinder, get some white cloth — old sheeting or worn handkerchief; cut several pieces about five inches square. Hold each one separately with a wire or tongs and set on fire. As the flame begins to die down, lay the charred cloth upon a smooth flat piece of tin or other metal and quickly cover with another metal. This cools and prevents the tinder from burning up. Lay two sheets of tinder upon some tissue paper and strike a rough edge of hard rock, such as flint or granite, against the sharp edge of the rod of steel so that sparks will fall upon the tinder. When a spark has ignited the tinder, gather up the paper and fold up about the sides to make a ball with a small opening, blow gently to increase the burning, and when it smokes strongly, blow harder. If the paper then bursts into flame, you will have had the experience of making fire by a method that was common a little over a hundred years ago. Our forefathers tried to keep a fire but would sometimes go to the neighbors to "borrow" live coals when their fire was all out. They kept tinder on hand so that in case of emergency they could produce fire by the "flint and steel" method, which is the method

Explain how the candle was lighted by the flint and steel method.

just described. But even the flint and steel was a big advance over the many centuries-old friction method with the bow and drill. Your great-grandparents doubtless thought of the wonderful way they had of making fire compared to the people of early times, just as you now think of the match as a wonderful device when compared to the flint and steel of former days. Friction with a match makes fire in a fraction of a second, but friction with the bow and drill under the best of conditions required minutes to make fire.

SELF-TESTING EXERCISE

Select from the following list those words which best fit the blank spaces in the sentences below. Arrange the words in proper numerical order. A word may be used more than once.

kindling	go	fire	same
temperature	temperatures	stops	burns
helps	burn	out	better
different	combustible	match	incombustible
below	lower	higher	friction
same	chemical	action	fuel
physical	air (oxygen)	stoves	goes

Fanning the kindlings placed on the glowing coals in a fireplace makes the fire (1)____ (2)____. Fanning a candle flame makes the fire (3)____ (4)____. In the first case there is much heat; fanning brings in more (5)____ and so (6)____ the burning. In the second case there is little heat; fanning brings in so much air that the (7)____ is reduced (8)____ the (9)____ temperature and so (10)____ the burning. There can be no burning or combustion unless a (11)____ substance is heated to its (12)____ (13)____ and supplied with (14)____. A common useful article making use of a combination of substances with different kindling temperatures is the (15)____. In early days of fire making (16)____ generated the heat. Today we have many devices using friction, but our ability to get fire so easily lies in the use of materials with (17)____ kindling (18)____. Sulphur takes (19)____ at a (20)____ temperature than wood.

STORY TEST

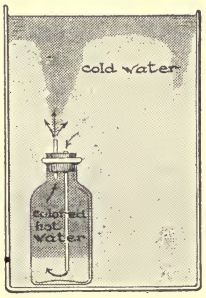
Does Jane Know How to Produce Heat?

Read carefully and critically. List all the errors and suggest corrections.

This is the way I learned to start a fire when I was a scout: Get a lot of dry leaves and lay them on some sticks of dry wood. If you have paper with you, crumple it and use it with the leaves. Lay large logs loosely over the mass of burning leaves. Substances with a low kindling point like phosphorus will take fire at such a low temperature that it is unsafe to hold them with the bare fingers. You can set fire to a thin shaving of pine easier than you can to a dry pine log because the shaving has a lower kindling temperature. A cold metal may extinguish a candle flame because it radiates heat so fast it cools the candle wax below its kindling point. In lighting a match, the first energy used is chemical, then heat and finally light result. There are only three changes of energy involved.

PROBLEM II. WHAT ARE SOME OF THE CHARACTERISTICS OF HEAT?

When we have a bonfire, we see that fresh air comes in to the fire, while smoke and gases rise from the fire. Such currents of air are called *convection currents.*



Demonstration 2. Convection.

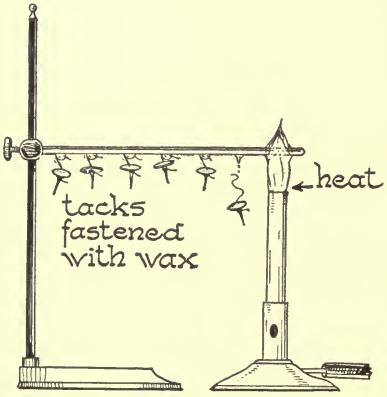
Fill a battery jar with cold water. Fill a small bottle with hot water colored with red ink; place in it a perforated cork containing two tubes, as shown in the diagram. Lower the small bottle of hot water to the bottom of the jar of water. What happens? Put in your workbook a diagram showing the movement of the water.

The movement of the liquid shown in this experiment is called *convection.* We thus see that convection takes place in liquids, and a bonfire shows that it takes place in gases. Since rising air or water is hot, heat is carried by it. What makes the heated water rise? This rise is caused by the fact that warm water is lighter than cold

water. Gravity therefore pulls with greater force on a given volume of cold water than it does on the same volume of warm water. Because of this greater pull, the cold liquid is drawn under the lighter one and pushes it up, thus causing a convection current. A similar explanation accounts for convection in gases.

Demonstration 3. To See if Heat Will Travel Along a Metal Rod.

Take a metal rod; attach it to a stand, as shown in the diagram. Tie threads to each of six tacks. Attach to the rod each of the threads about two inches apart by means of melted wax. Now apply heat to the end of the rod. What happens?



Conduction. This demonstration shows that heat travels from one end of the rod to the other. The flame heats the tiny molecules of iron, causing them to vibrate or move faster. They hit neighboring molecules harder blows and thus cause them to move. In this way, from molecule to molecule, heat travels by *conduction.* Most metals are very good conductors of heat. Substances like glass, water, and many rocks are fair conductors; while air, paper, linen, silk, and wool carry heat so poorly that they are called *nonconductors.* Poor conductors of heat are sometimes called *heat insulators.* Metals are the best and gases the poorest conductors of heat.

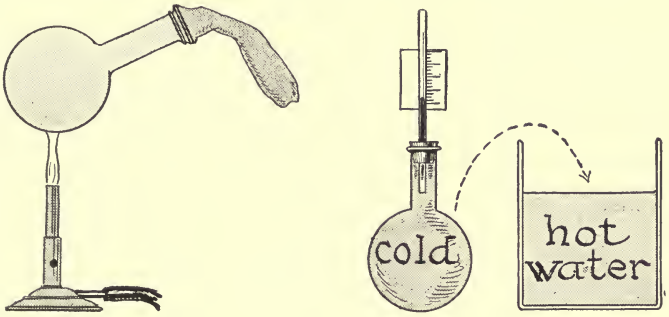
Radiation. The sun is 93,000,000 miles away from us, and we know there is very little matter in all of this space. Yet heat comes from the sun to us. This method of heat transfer is known as *radiation.* Experiments show that rough, black, dull substances absorb heat better than

smooth, light, or shiny substances. Substances which absorb heat give it up easily by radiation.

Demonstration 4. Heat Causes Expansion.

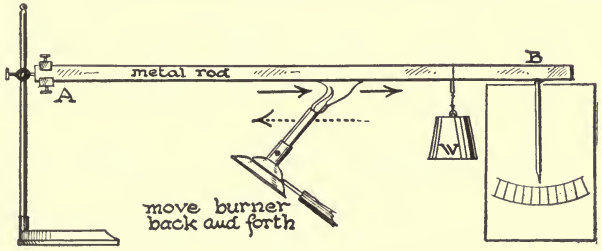
Gas. A glass flask filled with air having a balloon attached to one end is heated. What happens to the balloon? Let the flask cool. Result?

Liquid. Fill a 500 cc. flask full of colored water. Place a stopper carrying a long glass tube so that the colored water rises



in the tube. Mark the level of the water carefully on the tube. Now warm the flask by placing in a dish of hot water. What happens? Remove from the hot water and allow the flask to cool. Result?

Solid. Support a copper rod or tube two or three feet long on a block, as shown in the illustration. End *A* is not movable;



end *B* can roll over a wire bent so the end hangs vertically in front of the block. Hang a weight near *B* to hold the rod firmly upon the wire. Heat the rod by moving the gas flame back and forth along the rod. Watch the position of the wire pointer. Explain result. Let the rod cool. Explain the observed result.

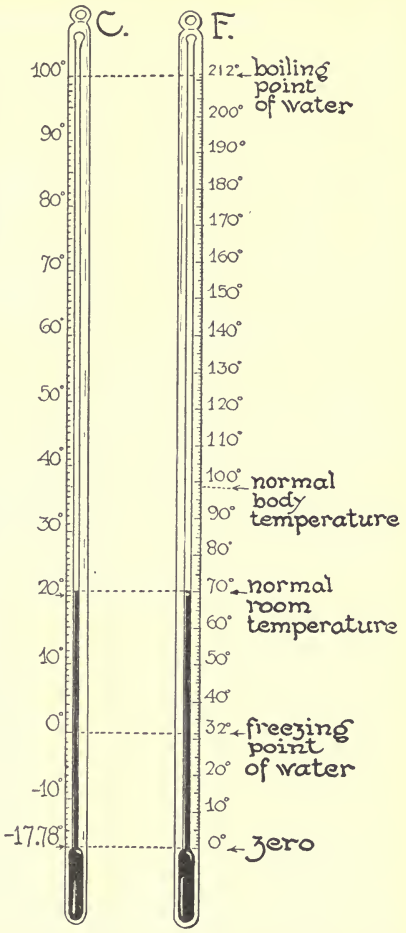
This demonstration shows very clearly that heat causes expansion. Contraction of substances is brought about when heat is withdrawn from them. On a hot day a metal drawbridge after being opened refused to come together again. Why? The drawbridge tender squirted a stream of cold water upon the bridge and it went back into place. Why?

How Temperature Is Measured. We have seen that heat makes things warmer, and the higher the temperature of a body, the more heat it contains. But heat and temperature are not the same thing. Temperature is the intensity of heat and is measured in units called degrees. This measurement makes use of the principle that matter when heated expands, and when cooled contracts. The thermometer is made of a glass tube having a very fine bore. A bulb at one end of the tube is filled with mercury or colored alcohol. Since heat makes the liquid expand, it will rise in the small bore in the tube as it gets warm and thus indicates the degree of heat which is marked on the scale.

Thermometer Scales. There are two thermometer scales, the Fahrenheit marked F., used by the weather bureaus and in everyday life, and the Centigrade marked C., used in scientific work and most foreign countries. The freezing point of water is 32° on the Fahrenheit scale and zero on the Centigrade, while the boiling point of water at sea level is 212° on the Fahrenheit scale and 100° on the Centigrade.

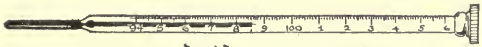
Heat Causes Changes in the State of Matter. Another thing that heat does is to change the form of different substances. The quantity of heat energy possessed by the molecules of water determines whether water is in the solid, liquid, or gaseous state. The molecules in ice have the least energy. Since heat is taken from warmer objects to change ice to water, ice is used in our refrigerators. Molecules of liquid water have more energy than molecules

of ice. A tub of water on a cold night gives up heat to the air. Fruits and vegetables do not freeze until the temperature is as low as 28° F.; and so tubs of water placed in farmers' cellars have many times kept fruits and vegetables from freezing. In changing water to steam at 212° F. a large amount of heat is stored in the molecules of steam. This energy may be used in cooking, in heating, and in the production of mechanical energy by means of the steam engine. When steam condenses to a liquid, all this stored heat is given off. That is why a burn by steam is so much worse than a burn by boiling water. Both are the same temperature, but the steam has more heat in it.



If butter melts at 93° F. it will melt at what temperature Centigrade?

Freezing and Boiling Temperatures. Water freezes and ice melts at 32° F. It seems strange at first to think of water and ice at the same temperature. But when just enough

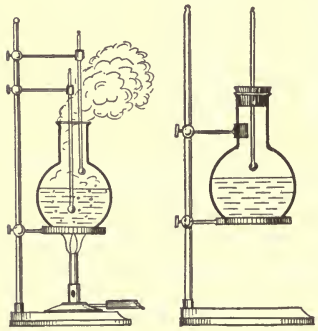


clinical thermometer

How are clinical thermometers used?

In how many ways is heat energy used in the kitchen?

heat is added to ice at 32° to melt it, the resulting water also is at 32° F. There is no change in temperature when ice melts or when water freezes. Water boils and steam condenses at sea level at 212° F. During this change of state there is no change in temperature.



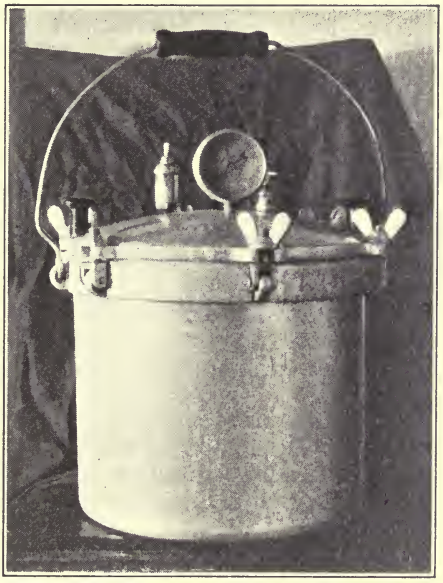
Demonstration 5. Boiling Water.

1. *Constant Temperature of Steam and Boiling Water in Open Vessel.* Heat water in a flask. Have two thermometers, one placed so that the bulb is in water and the other so that it will be in the steam above the water. After the water is boiling, read the thermometers at intervals of one minute for five minutes. Tabulate your results. What are your conclusions?

2. *Boiling Water at Reduced Pressure.* A ring-neck, heavy-walled, round-bottom flask is filled half full of water. Boil the

water until the air has been driven out. Remove the heat. Close the flask with a stopper holding a thermometer. As the steam condenses, the pressure on the water is reduced. After the bubbling has stopped, condense more steam by placing a cold wet cloth or ice around the upper half of the flask. Does the water boil again? At what temperature did you boil water? After the temperature gets below 90° C. or 190° F. and there is no boiling, place the heat under the flask for a moment. Result?

Why Pressure Cookers Are Useful. At sea level water under average atmospheric pressure boils at 212° F. Both water and steam have the same temperature. People who live on high mountains find that water boils before it reaches 212° F. This is because the pressure of the air is less and the boiling point of water depends upon the pressure on its surface. On some high mountains boiling water is not hot enough to cook vegetables, so they must use some other method or inclose the water in a vessel to prevent the escape of steam. The increased pressure raises the boiling point and makes cooking possible. In the pressure cooker where steam is not allowed to escape, the pressure increases and the temperature rises with the rise in pressure. This accounts for the more rapid and thorough cooking of foods



Wright Pierce

In what ways is a pressure cooker useful? Why would it be useful at high altitudes? What scientific principle underlies this value?

cooked in such vessels. Pressure cookers are commonly used in high altitudes, but are also used advantageously at low levels chiefly to save time in cooking, to save fuel, and to make tough cuts of meat more tender.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

matter	state	heat	hot
cold	temperature	under	thermometer
pushes	particle	increases	contract
larger	weight	decreases	change
conduction	force	expand	substance
more	conductors	radiation	reduction

Gravity pulls on one cubic inch of cold water with (1)____ force than it does on one cubic inch of (2)____ water. As a result, the (3)____ water flows in (4)____ the (5)____ water and (6)____ it upward. Heat is transferred from particle to (7)____ in (8)____ by a process called (9)____. Metals are better (10)____ of heat than clothing. (11)____ is not always required to carry heat; in the transfer by (12)____ heat can pass through empty space. When most substances are heated, they become (13)____ or we say they (14)____. The measurement of (15)____ by means of a (16)____ takes advantage of the (17)____ in size of bodies when heated to a higher temperature and of its (18)____ in size when it is cooled. Many substances like ice and lead, when heated, may (19)____ their (20)____ and become liquids.

STORY TEST

Fred Is at the Microphone Today Telling "What Heat Can Do"

Read carefully and critically. List all the errors and suggest corrections.

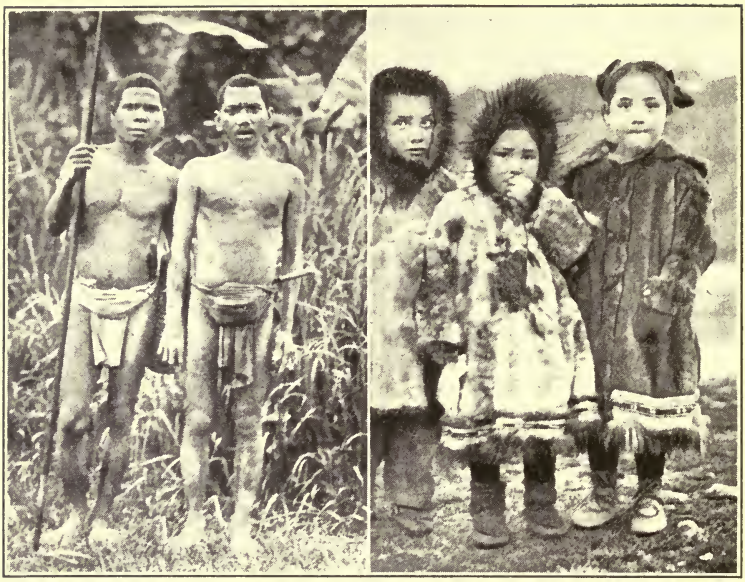
Fellow science students: From my study of heat I have come to the conclusion that heat is a sort of circus trickster. He can get aboard the molecules of air coming from the throat of a trumpeting

elephant and rise to the top of the big tent with no apparent support in a process called conduction. He also can walk a tight wire. You recall how when you hold one end of a metal in the flame, heat comes over and tells you to let go. This method of travel is called radiation. Heat is an austere master; when he gets inside a vessel of water and cracks his whip the molecules of water cower and crowd together making the volume smaller. Heat is a fickle fellow and changes partners often. Believe it or not, he likes ice cream. I was called away from dinner last night when half through my ice cream dessert and when I came back just a pasty liquid was left. Why? Because heat had left the air and gone into the ice cream. They call this a change of state but I call it meddling. There is an instrument called the barometer which is used to tell how hot or cold a body is. I had one under my tongue once. Heat went into it from me and made me feel a lot cooler.

PROBLEM III. HOW DOES CLOTHING AFFECT THE HEAT OF THE BODY?

What Keeps the Body Warm? We have already learned that the heat of the body is caused by the oxidation of food which we eat. The circulation of the blood assists in keeping all parts of the body at about the same temperature. But we know that on a cold day the outside of the body gets cold. We use clothes, bedclothes, hot-water bottles, or electric pads to keep warm. Evidently clothes should be worn not only for their good looks but for their practical value. In hot climates little clothing is needed, while in very cold parts of the world furs and skins act as insulating materials against the cold. In a temperate climate where changes are frequent clothing ought to be adjusted to fit the temperature.

What Materials Are Used in Clothing? We know that most of our clothing comes from five sources. Outside of leather and rubber, our clothing is made from fibers of wool, cotton, flax, silk, and rayon. Wool and silk are of animal origin; cotton and linen (from flax) are of



Two extremes in clothing. Give scientific reasons for the two conditions in clothing shown here.

vegetable origin. Rayon is a chemical product made from vegetable matter such as wood pulp and low-grade cotton.

Demonstration 6. Fibers and Tests for Fibers.

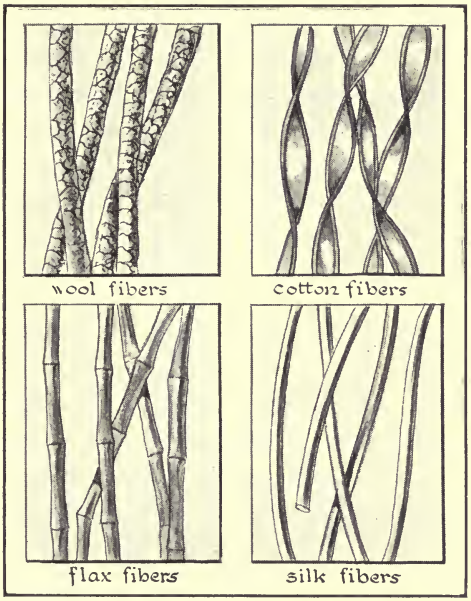
Physical Appearance of Fibers. Examine under the microscope, slides of wool, cotton, flax, silk, and rayon. Wool fibers have little scales projecting from the surface. Cotton fibers look twisted. Flax fibers are never twisted, vary in size, and have small transverse markings. Silk fibers have no markings, are smaller in diameter than flax. Rayon fibers are smooth like silk but much longer. Place in your workbook sketch drawings showing the appearance of the different fibers.

Absorption-of-Water Test. Place small equal-sized samples of cloth made of the different fibers in saucers containing equal amounts of water. Which absorbs the most water? Which the least?

Chemical Test. Boil each of the five different kinds of cloth in a lye solution (5 per cent sodium hydroxide). Wash carefully in

water before handling. Test the strength of each cloth. Which cloth holds together the best?

Burning Test. Using the five kinds of cloth, light each piece separately. Notice the odor and rapidity of burning. Repeat the test, holding strip of moist blue litmus paper in the smoke given off by the cloth. What happens? Do the same with moist red litmus paper. What happens? Sum up all your observations in your workbook.

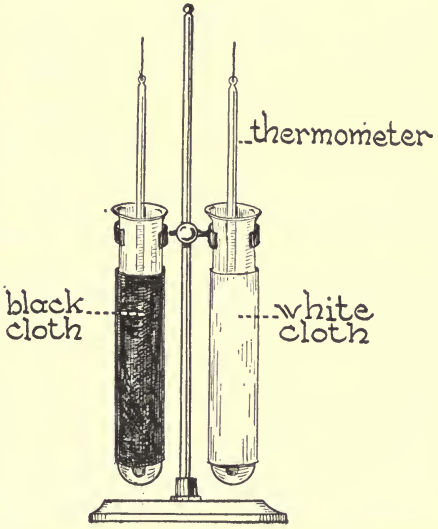


What These Experiments Show. Wool fiber because of its scales gives garments their rough texture. When such fibers shrink, as they may when passing from hot to cold water or to water containing such a substance as lye, the scales cause the fibers to stick close together. Wool undergarments absorb moisture and allow it to evaporate slowly. This prevents rapid loss of body heat. Cotton underwear leaves an excess of moisture on the skin and the moisture may evaporate rapidly, thus chilling the body. The twist in the cotton fibers serves the same purpose as the scales on the wool: it gives spring and elasticity to the material. Cotton fabrics are harder than wool, and there are fewer air spaces in cotton materials than in wool, hence cotton garments permit heat to escape more rapidly from the body. Linen fibers have little elasticity and hence the fabrics manufactured from them do not shape

themselves to the body. Linen can be washed in hot water without injury, but it is costly and so is not used as much as cotton. Silk both absorbs and loses water rapidly, but it is expensive and hard to wash. Rayon which is made largely from wood pulp is used extensively for underwear. It absorbs water readily and loses it rapidly, and consequently makes good undergarments.

Clothing for Winter and Summer. The human body is a self-regulating machine in which the body temperature is normally kept at 98.6° F. Underneath the skin is a fine network of blood vessels from which heat is passed off through perspiration. When we do hard work, the blood becomes heated and circulates more rapidly. The blood vessels of the skin get larger, and give heat off to the sweat glands, which pour out perspiration. This in turn evaporates, cooling the skin, and this cools the blood; thus our temperature is kept constant. Evidently, then, in winter we need underclothes which will not let heat out. Underclothes which do not hold moisture are best because wet, sticky undergarments cool us by conduction if it is cold, and keep us uncomfortably hot by preventing evaporation if it is warm. It does not make very much difference what kind of materials are used, provided the underclothes are porous. Woolen underclothes are best for winter, because the curly fibers make them porous, and because they absorb moisture and give it up slowly, thus preventing the skin from being cooled too rapidly. We have seen that dark substances absorb heat and light-colored substances reflect heat; therefore, to wear dark clothes in winter and light clothes in summer is scientifically correct as well as more comfortable. If you take two test tubes, place a thermometer in each tube, then wrap a piece of white cloth around one and a piece of dark cloth of the same weave around the other, leave both tubes in the sun side by side for a few minutes, and then read the

temperatures, you will find that the tube surrounded by the dark cloth shows a higher temperature than the other tube. Evidently absorption of radiant energy has been the cause of this difference in temperature. In the winter we wish to put a nonconductor between the body and the outside cold air. For this reason fur coats and other dense materials are used. We sometimes place a newspaper over our chest when going into a cold wind. Can you explain scientifically the reasons for this?



In which tube will the thermometer register higher? Why?

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

reduces	heat	light	replaced
98.6	wool	fibers	heats
loss	shrink	absorbs	smoothness
silk	rayon	elasticity	evaporates
scales	air	dark	silky
76.4	rubber	stretch	hot
warmth	nodes	cold	wool

In cold regions clothing is very useful to prevent (1)____ of (2)____ from the body. Of the animal fibers (3)____ and (4)____, (5)____ is the more common while (6)____ make more beautiful fabrics. In recent years (7)____ has to a large extent (8)____ silk because of its low cost. The rough texture of wool is due to

(9)____ which when a garment is rubbed, especially in hot water, cling together, causing the garment to (10)____. Much of the warmth of any garment is due to the (11)____ held within the meshes of the cloth. The normal temperature of the body is (12)____ F. Evaporation of water from the surface of the body (13)____ the temperature. In winter (14)____ colored clothing is warmer than (15)____ colored clothing because it (16)____ more heat.

STORY TEST

ELISE GIVES US SOME IMPORTANT FACTS ABOUT CLOTHING

Read carefully and critically. List all the errors and suggest corrections.

Ever since it was found that fibers could be spun into thread and then woven into cloth, man has had many different kinds of materials from which he can make his clothes. Whether it is the silky rayon made by the silk worm or the linen fibers taken from the seed of plants, it is possible to weave it into many pretty patterns. You can tell true rayon from animal silk because it burns with odor of burning feathers and shows nodes along a smooth rod when viewed under a microscope. Cotton can be told from wool because it burns faster and dissolves in alkali. Yesterday I had a temperature of 94.7° F. and Mother kept me in saying I had a fever because the normal temperature is 89.6° F. When we work hard, we increase the body heat and perspiration. Evaporation of the perspiration is a cooling process and so helps to keep the body temperature down to normal. We should choose clothing which checks evaporation in winter and aids it in summer.

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. In this unit look carefully for other generalizations than those which follow:

1. Heat is present to some degree in all matter.
2. Our greatest source of natural heat is the sun.
3. Heat is produced from other forms of energy.
4. Heat can be transferred through matter or by radiation.
5. Heat causes many changes in matter.
6. Heat is essential to the human body.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure to know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all the statements you believe to be correct. Under the second place all the numbers you believe to be incorrect. Your grade = right answers* × *2.*

I. **Before we can start a fire we must have:** (1) heat; (2) nitrogen; (3) oxygen; (4) an incombustible substance; (5) inflammable material.

II. **Heat travels from:** (6) the sun to the earth by conduction; (7) a flat iron to clothes being ironed by conduction; (8) hot coals to a kettle above by radiation; (9) a soldering iron to the solder by convection; (10) a fireplace to objects in the room by conduction.

III. **When heat is applied to water, it may change its:** (11) temperature; (12) state to a solid; (13) size; (14) weight; (15) composition.

IV. **The temperature of boiling water is:** (16) 32° F. at sea level; (17) less on tall mountains than at sea level; (18) greater in a partial vacuum; (19) never over 212° F. in a pressure cooker; (20) always the same 98.6° F.

V. **There is a change in temperature when:** (21) water cools; (22) water at 32° F. changes to water at the boiling point; (23) steam at the boiling point condenses; (24) ice melts; (25) a hot iron is put into cold water.

VI. **The principle of heat insulation is used when we use:** (26) storm windows; (27) the pressure cooker; (28) hot-water bottle; (29) asbestos mats on the table; (30) copper for hot-water pipes.

VII. **Wool fiber:** (31) is a fine, flattened, and twisted fiber; (32) will dissolve in a 5 per cent sodium hydroxide solution; (33) absorbs water more freely than cotton; (34) conducts heat well; (35) burns faster than linen.

VIII. **Cotton fiber:** (36) gives the odor of burning feathers when burned; (37) will dissolve in a 5 per cent sodium hydroxide solution; (38) is a thick, lustrous fiber; (39) has the same chemical composition as the material from which rayon is made; (40) is a vegetable fiber.

IX. **Silk fiber:** (41) is of animal origin; (42) has a more brilliant luster than any other fiber except rayon; (43) has little scales projecting from its surfaces; (44) is composed of cellulose; (45) is stronger than artificial silk when both are wet.

X. **In washing woolens it is well to use:** (46) boiling water; (47) soap containing free alkali; (48) little soap but much washing soda; (49) water below boiling point; (50) a small amount of bleaching powder.

THOUGHT QUESTIONS

1. Make a list of materials which have a low kindling temperature; a high kindling temperature. Which of these would be best to build a fire with?
2. Find ten ways in which heat insulators are used in your home.
3. Why is the outside of a teakettle kept bright and smooth while the bottom is dull, black, and rough?
4. Why does a bicycle tire register greater pressure on a hot day than on a cold day?
5. Why is it when you fill the radiator of your car full to the brim on a cold day that it begins to run over shortly after you start the car?
6. You are going to Duluth for your Christmas vacation. What clothes would you take with you, and why?
7. You are driving from New York City to Florida in March. What clothes would you wear on the trip? Give your reasons.

REPORTS ON THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. Everyday activities involving expansion.
3. An account of the work of Bunsen or of Fahrenheit which is related to heat.
4. Uses of heat insulators.
5. How man's activities and habits vary at different latitudes on the earth.

SCIENCE RECREATION

1. **Pressure of ice.** Fill a small bottle with water. Put a cork in tightly. Be sure there is no air space left inside. Put this either in the ice-cube pan and put into the cooling coil of the refrigerator, or place it outdoors on a day when the temperature

is under 25° F., or pack it in a mixture of crushed ice and coarse salt. Examine after two hours. Account for the result.

2. **Cast lead weights.** Make exactly 1 oz., 2 oz. to use on a letter scale. Cast lead toys.

3. Make a study of heat-conducting materials used in your home and write a report upon them.

4. Make a study of heat-insulating materials used in your home and write a report upon them.

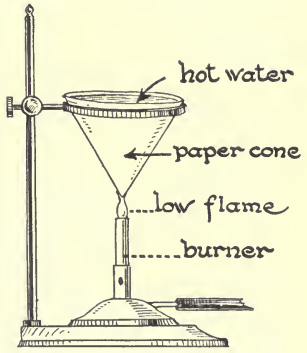
SCIENCE CLUB ACTIVITIES

1. The Force of Steam

Put a cupful of hot water into a half-liter flask. Stretch the open neck of a rubber balloon over the opening of the flask. Fasten the flask to ringstand with a clamp. Boil the water, being very careful not to allow the flame to come near any part of the rubber balloon. Continue the heating until the steam escapes into the room. Have the club members stand several feet away until the climax is over.

2. Boil Water in a Piece of Paper

Get a piece of stout paper of medium thickness about 5″ or 6″ square. Fold this to make a conical cup. Have the fold come inside the dish so that outside there is only one thickness of paper between the water inside and the flame outside. Place the cup in a ring on the ringstand. Trim off the paper that is more than $\frac{1}{4}$″ above the top of the iron ring when the cup is filled with water. Put hot water in the cup to start with, and place a low flame under the cup. Heat until you see the water boil.



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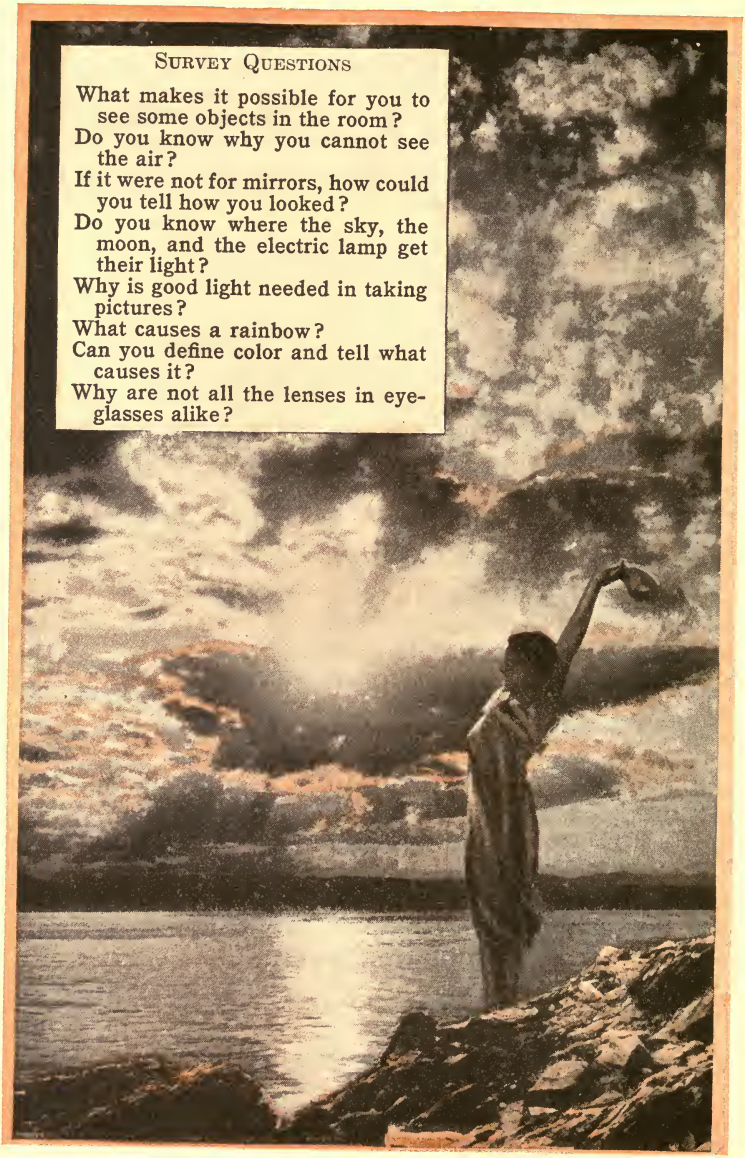

Survey Questions

What makes it possible for you to see some objects in the room?
Do you know why you cannot see the air?
If it were not for mirrors, how could you tell how you looked?
Do you know where the sky, the moon, and the electric lamp get their light?
Why is good light needed in taking pictures?
What causes a rainbow?
Can you define color and tell what causes it?
Why are not all the lenses in eyeglasses alike?

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UNIT VI

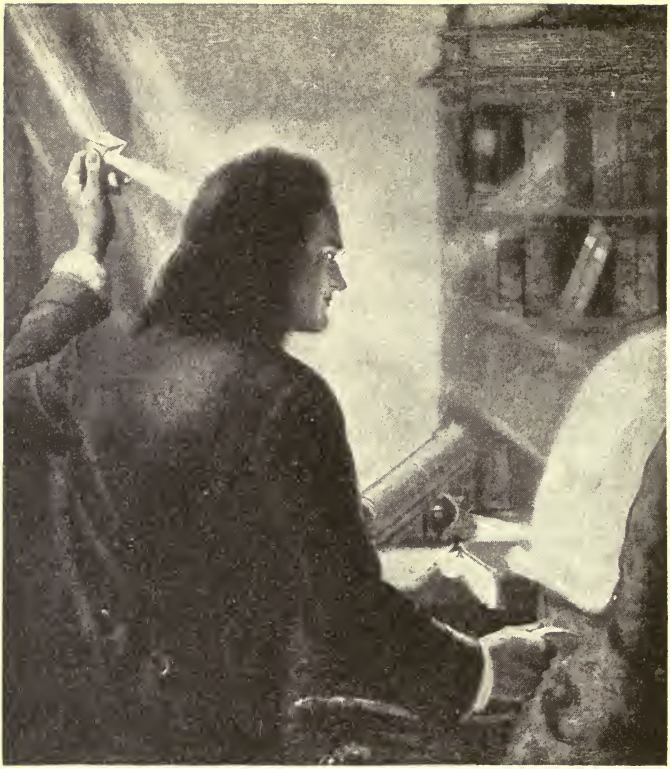
HOW WE USE LIGHT

PREVIEW

Have you ever awakened from sleep on a dark night to find yourself in utter darkness? How glad you were to have an electric light close at hand! What a sense of helplessness we get when we are without any light! We certainly enjoy light, for it gives us so much: our ability to see views and pictures, to read, to see wonderful sunsets, the colors of birds and flowers, or the gray vastness of the desert. It gives us our food, for we know green plants depend upon it.

Sir Isaac Newton, a great English scientist of the seventeenth century, believed that light consisted of very small particles given off at great speed by all luminous bodies. He thought that when these particles struck the eye, they produced the sensation of light. This theory was accepted by scientists for over a hundred years, and then discarded in favor of a theory suggested by a Dutch physicist, Huygens.[1] This theory stated that all luminous bodies caused the ether, which was supposed to fill all space, to vibrate. When these vibrations reach the eye, they give the sensation of light. Recently a new discovery by a German and an Indian professor give other ideas. This is the so-called Quantum theory which is based on the belief that light proceeds in little gusts or packets of energy instead of continuous waves. Still another theory goes back to that of Newton and says that light travels in the

[1] Christian Huygens (hī'gĕnz), Dutch astronomer and physicist, 1629–1695.



Bausch & Lomb Optical Co.

SIR ISAAC NEWTON, 1642–1727.

NEWTON must have been a clever boy, for although he did not do well in school he was very ingenious. He made a clock which ran by water, a sun dial, and a windmill which actually ground corn.

At the university he specialized in mathematics and science and soon showed his genius. He improved methods of calculation in mathematics and applied them in physics; he invented the reflecting telescope; he made navigation safer by making certain the positions of the heavenly bodies; and he proved the pull of gravity was a universal law.

Newton's experiments with a glass prism and a beam of sunlight were the beginnings of spectrum analysis, which is now a useful tool of the scientist. The spectroscope, making use of the prism principles, is particularly useful to the astronomer.

After over 40 years of service in Cambridge University he died, one of the most honored men of his time.

form of tiny balls, each of which is spinning very rapidly in space. In this book we will agree with the theory that light is a form of radiant energy and that it passes through space by means of very rapid vibrations. Light travels at the astonishing rate of over 186,000 miles a second. When a candle is lighted, there are changes in the material of which it is made, which produces light energy. This radiates through space in all directions. Heat is also radiated from hot bodies, and the disturbances in the aërial of a broadcasting station send out electrical radiations. Evidently, then, light, heat, and electricity may travel as forms of radiant energy. It will be the purpose of this unit to learn something about the ways in which light is used in our everyday life.

PROBLEM I. HOW DO I USE LIGHT?

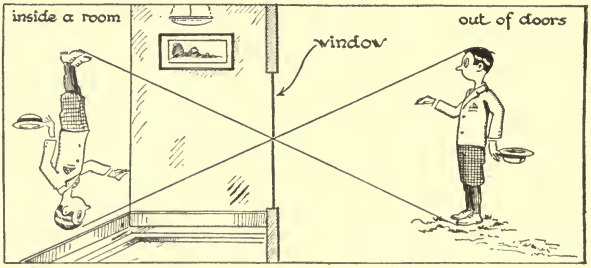
If you were ever up to see the sunrise, you know that as daylight approaches, objects begin to change from hazy gray outlines and become more and more distinct as light falls on them, till, in the early sunlight, they appear in all the colors of nature. We have just read that light is a form of radiant energy. We know that light is frequently associated with heat, and that plants in the garden get heat energy as well as light energy from the sun. Recent discoveries have shown that we, ourselves, are getting good out of the light that a few years ago we had no idea of. The ultra-violet ray in the sunlight aids us to keep well and prevents certain diseases, while the hardness of our bones and our freedom from certain diseases is due to its effect. We know that light makes it possible to read, to see things in their natural colors, as well as to take pictures and make light signals. From times of earliest civilization people used light for signaling. The Greeks and Romans as well as our American Indians all had elaborate light signals, just as we are warned today by our

lighthouses, airplane beacons, and the more common traffic lights. Heliograph signals, made by reflecting a beam of sunlight on a mirror, have been sent nearly 200 miles.

The Indians used smoke signals. By fanning the fire puffs of smoke were given off.

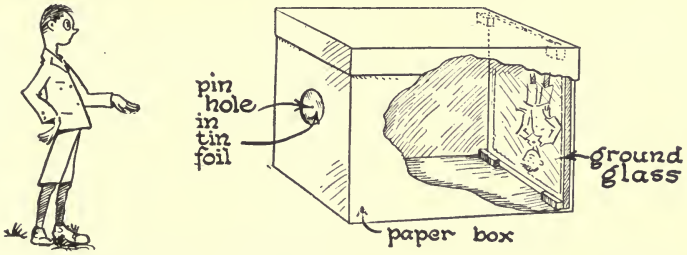
Light-Using Devices. Let us think over the things we may find at home whose use depends upon light. There is the camera, the opera-glass, the reading glass, and, of course, the mirror and windows. Perhaps there is a magnifying glass, an enlarging mirror, or a bull's-eye flash lamp. Among the toys there might be a kaleidoscope and possibly a stereoscope. If there is a nature lover in the family, you may find bird glasses or field glasses.

How an Image Is Made by a Pinhole. If you let a small beam of light enter a dark room in which there is



dusty air, you can see that the light travels in a straight line. If a small hole is made in the window shutter on the first floor of a building and the room is dark, people

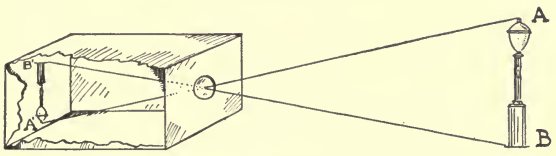
who walk by the window outside will reflect rays of light so that images of them appear on the wall opposite the window. A curious thing about the image is that it is upside down. If we make a pinhole in one end of a small



How many devices can you name that involve the principle shown here?

box and have a shaded frosted glass in the opposite end, we can see on the frosted glass an inverted image of a bright object that is in front of the pinhole.

The diagram will help us to understand this. A is seen by light that comes from A. The light that goes through the pinhole will fall at A′. The light from B will reach the frosted glass at B′. Light from all points between A and B will fall somewhere between A′ and B′. The image is inverted because the rays which come from the object cross where they pass through the pinhole. If the hole were not very small and other light was not kept out,



there would be such overlapping of light from different parts of the object that no clear image could be seen. This principle of image formation is used in our eyes whenever we look at any object. There is one difference. There is a lens at the opening of the eye. This allows more light to come in and gives a brighter image. The

Galloway

How many different kinds of stop lights have you seen? It would be a good thing to have these signals uniform for all parts of the country. Can you see why?

image in the back of the eye excites the proper nerve endings so that the brain can interpret the image and in this way we see objects.

Colored Signal Lights. The engineer depends upon colored lights to tell him if there is a clear track ahead. Where other trains use the same track and where switches may lead to branch tracks, a green light is a signal that the track is clear and safe. A red light is the signal for danger. On boats you see green lights on the starboard or right side and red lights on the port or left side. If we travel by train or water, our safety depends greatly upon the watchfulness of the pilot or engineer and his care in heeding signals. Our most common use of signal lights is the traffic signal and automobile tail light. Here again red is the danger sign and green the signal to pass. In

many places the use of an orange light for pedestrians to pass while auto traffic remains at rest is a very helpful aid to safety. Our use of colored lights and following the messages they bring to us make possible the rapid clearing of traffic jams and greater freedom from accidents.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

radiation	radiant	orange
chemical	mechanical	red
electricity	image	blue
lights	cross	inverted
heat	green	object
colored	straight	light

Light is a form of (1)____ energy just as (2)____ and (3)____ are. (4)____ is used whenever we read or see an object. Since light travels in (5)____ lines, whenever light from an object passes through a small opening, the rays (6)____ and produce an (7)____ image. When (8)____ signal (9)____ are used, it is common to use (10)____ for danger and (11)____ for safety.

STORY TEST

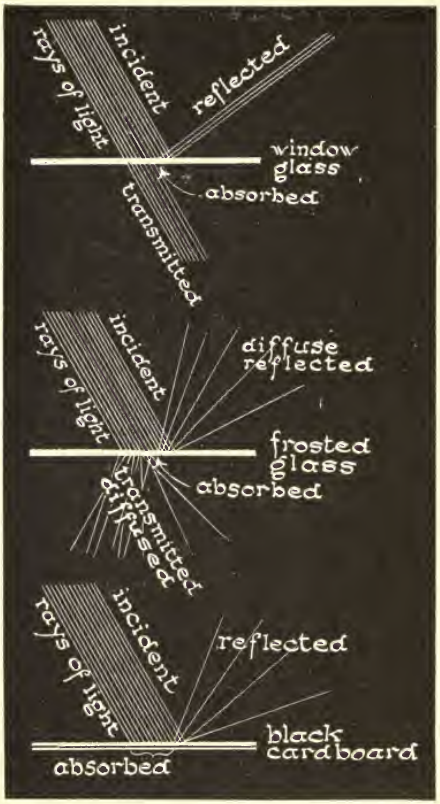
Florence Writes an Essay on Light

Read carefully and critically. List all the errors and suggest corrections.

There are two kinds of light, black and white. This has been proven by pictures taken of lightning. Some streaks are black and are produced by black lightning. We cannot see objects by black light; we use the white light. If a candle is behind a block of wood, we cannot see it because light travels in straight lines. If light radiates from a red hot iron, the light goes in all directions and then may go around corners, in curved lines. If light rays from two objects were to meet, they would destroy each other, and where they come together, the two bodies would be invisible. The reason automobiles have red headlights is because it is dangerous to be in front of a car. The green tail light indicates safety.

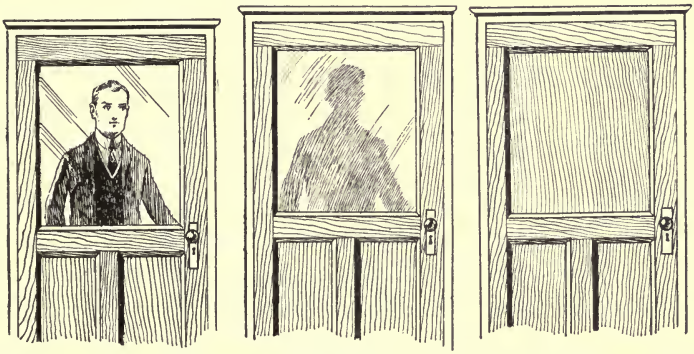
PROBLEM II. WHAT ARE SOME OF THE PROPERTIES OF LIGHT?

What Happens When Light Meets a Body? It is interesting to play with a beam of light. In a dark room allow a small beam of light to pass across the table from a lantern. Make this beam visible by means of dust, smoke, or ammonium chloride fumes. Hold a piece of window glass at right angles to the beam. You can see the beam almost as brightly back of the glass as in front. This light that comes through is *transmitted* light. Tilt the glass and you will see a faint beam sent off from the surface. This is *reflected* light. A still smaller part of the beam is neither transmitted nor reflected, but is *absorbed* and changed to heat. Three things happen when a beam of light comes to a body that allows light to pass through, but only two things happen when the body does not permit the light to pass through. Can you tell what happens to the light when it meets the latter body?



Explain why the frosted glass has a different effect on the light than the window glass does. What happens to most of the light that falls upon a black body?

Bodies Vary in Ability to Transmit Light. Have you ever noticed how the "steaming" of a window at home or on the train changes your vision of objects on the other side? If you wear glasses, perhaps you have noticed that when you come into a warm, damp atmosphere from the cold outdoors the moisture gathered upon your glasses so that you could not see anything distinctly. When you wiped off the moisture or it disappeared after the glasses were warmed you could see clearly again. Clear glass lets light go through without much change in

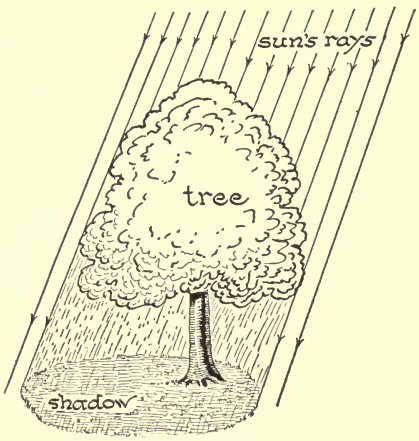


Explain the terms transparent, translucent, and opaque by reference to the diagram.

direction. All bodies like glass, cellophane, quartz, air, and water which permit light to pass through so that we can see objects through them clearly are called *transparent.* Making the surface of glass rough causes a scattering of light that passes through. Frosted glass, condensed vapor on glass, oiled paper, and very thin paper, gauze, or window shades may allow enough light to pass through to show the presence of objects without their being seen distinctly. These bodies are *translucent.* Objects that cut off all light are called *opaque.*

A Shadow. If you darken a room and allow a beam of light to enter, you will notice that it travels in a straight

line, and that if you put an opaque object in front of the source of light, it will cut off the light and produce a shadow. A shadow is that space from which light is cut off. The dark outline we cast on the pavement when we stand near a street lamp we often call a shadow. But remember a shadow is not just a dark surface, it is all the darkened space back of the object which cuts off the light. Were this not so, we could not enjoy the shade (shadow) of a tree having dense foliage on a bright hot day in the summer.

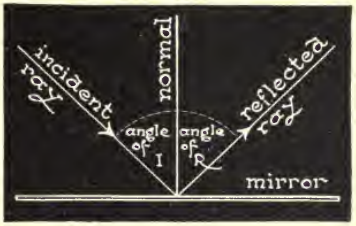


Where is the shadow? Is the word "shadow" put in the correct place in this cut?

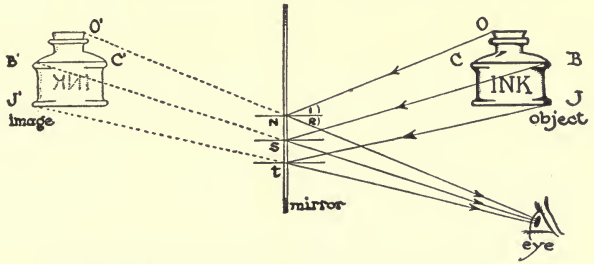
Reflection of Light. Light, such as a candle flame, a red hot iron, a burning match, or the stars may come to our eyes direct from its source. Bodies which give off light of their own are *luminous* bodies. Very few of the objects we see in the course of the day are bodies that have light of their own, but we cannot see any object unless light comes from it into our eyes. All nonluminous bodies which we see receive light from some other source and reflect it. That which is reflected into our eyes makes the object visible to us. Do you realize how important reflection of light is? Without it you could not read, see pictures, nor recognize friends by sight. You could not see the moon nor yourself in a mirror. Sunlight which enters your room may be reflected from one surface to another many times before it is reflected by the particular object you may be looking at.

Demonstration 1. Law of Reflection.

Hold a plane mirror in a narrow beam of light in a dark room. The light is bent or reflected from the mirror. We call the incoming ray the *incident* ray and the outgoing ray the *reflected* ray. A line at right angles to the surface where the ray of light meets it is called a *normal*. Hold a ruler at right angles to the mirror at the point where the beam strikes the mirror, compare the angle between the ruler and the beam coming to the mirror (angle of incidence) and the angle between the ruler and the beam going from the mirror (angle of reflection). Turn the mirror slightly to change the angles. Compare the angles as before. What do you notice with reference to the angle of incidence and the angle of reflection? When light is reflected from a plane surface, how does the size of the angle of reflection compare with the size of the angle of incidence?



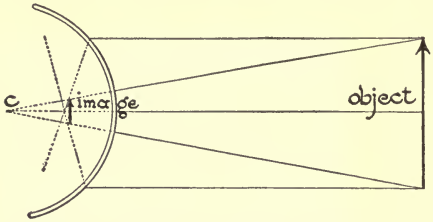
How We See in a Mirror. When you look into a mirror, the image appears to be behind it. If you step close to the mirror, the image comes close; if you step away, the image goes away. If you examine the diagram, you will see that light goes to the eye in the direction it would if the object were really where the image is, but in reality it goes from the object to the mirror, which reflects it to



If the image is behind the mirror why can you see it?

the eye. How does the distance *ON* compare with the distance *O'N?* How does the angle *I* compare with the angle *R* at *N?* At *S?* At *T?* The image we see is an

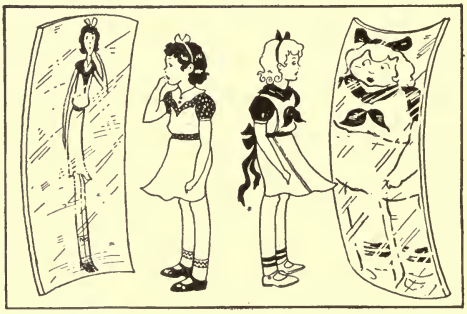
unreal image because there is no light that really goes to the place where we appear to see the image. When a real image is formed, as in a camera, rays of light actually form the image where the image is seen.



Does this convex mirror give a real or an unreal image?

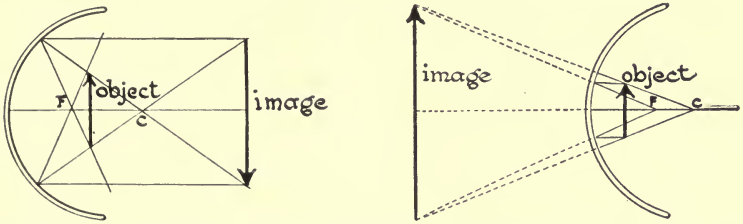
Curved Mirrors. You have probably seen a crystal globe. This is a spherical mirror. A small portion of the spherical surface would also be called a spherical mirror. It is also a convex mirror. Sometimes a convex mirror is placed on the fender or on an arm projecting to the left of the wind shield of a truck or automobile. The curved surface makes a larger area visible, and an image is seen just as in a plane mirror except that it is smaller. Perhaps you have looked into the convex cylindrical mirrors at some amusement park and have seen yourself tall and thin or short and fat.

The inside of a spherical surface is concave. A concave mirror will focus rays of light from a distant object and make a real and enlarged image. Large mirrors of this type are used in the reflecting telescopes for viewing the stars. Enlarging mirrors are useful and can readily be obtained. The dentist uses a small enlarging mirror to see your teeth



How to look stout or thin. Why do some mirrors change your appearance?

when filling them. A point equally distant from all points on the surface of a curved mirror is the *center of curvature C.* The point where parallel rays are brought



Where must an object be located with respect to *F* (focus) and *C* (center of curvature) of a concave mirror to produce an enlarged real image? An enlarged unreal image?

together after reflection is the *principal focus F.* This focal point is about half way from the mirror to the center of curvature. The position of the image depends upon the position of the object. In science the unreal image is usually called a *virtual* image. A concave mirror is used for auto and locomotive headlights and for search-lights. When a light is placed at a certain point in front of the mirror, it sends out a powerful beam of nearly parallel rays.

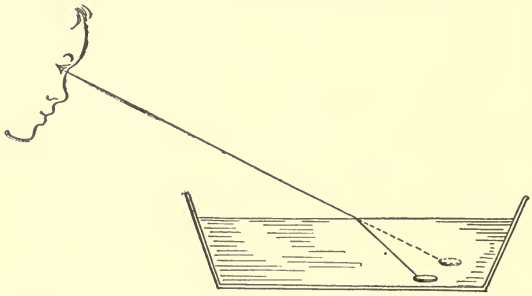
Diffused Light. When a beam of parallel light rays strikes a smooth surface, it will be reflected in a beam of parallel rays from the surface; but if it strikes a rough

Why does a rough surface diffuse light? Does the same law of reflection hold in the two cases?

surface, the light will be thrown off in different directions and scattered. Such light is *diffused.* Light from the sky

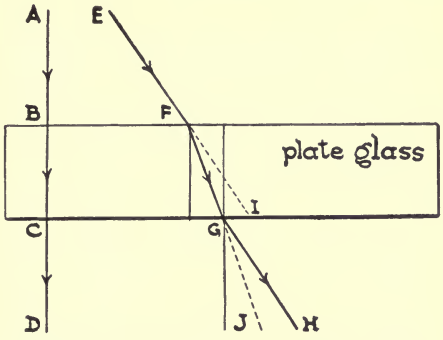
is diffused, because air is filled with countless millions of tiny irregular dust particles. These particles divert the rays of the sun out of their straight course and give diffused light. Without the atmosphere to diffuse the sun's light, the earth would look very different because contrasts would be much greater than they are now. The whole sky would appear black in the daytime except for the luminous disk of the sun and the points of light made by the stars. In winter our north windows would receive no light at all. It is fortunate for us that the atmosphere with its particles of dust and moisture diffuses light.

Refraction of Light. A famous English philosopher once noticed that if he put a coin in a cup and then stood away from it so that he could just not see it, when he poured water into the cup, the coin came into view. This curious happening is brought about by the fact that light travels more slowly in a dense than in a less dense material. When light enters the water, it slows up and is bent from its course. There is one exception: a ray of light passing into another medium of different density at right angles (90°) to the surface between them is not bent, but continues on in the same straight line. But when any oblique ray of light passes from air into water, it will be bent toward the perpendicular; and when it goes from water to air, it will be bent away from the perpendicular. The bending of light rays when they pass from one transparent body to another of different density is called



Which is the real and which the apparent position of the coin?

refraction. We appear to see objects in the direction in which the light enters our eyes. Consequently if the rays of light are bent before reaching our eyes, there is an apparent displacement of the body. For this reason water in a pond appears to be more shallow than it really is. In other words, the earth at the bottom of the pond looks to be nearer the surface and has often deceived adventurous boys and girls who could not swim. Fish in the water may not be in the exact position in which you are looking when you see them. It is refraction that bends the rays of sunlight in a burning glass or lens and that makes letters look larger in a reading glass.



Passage of light through plate glass. Why is only one of the rays bent?

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

reflection	right	translucent	convex
refraction	opaque	diffused	concave
reflected	transparent	same	plane
bent	luminous	front	smooth
send	light	back	directions
bend	dark	inside	angle
left	equals	outside	image

When a beam of light comes to a window at a (1)____ angle, some of the light is (2)____ back in the direction from which the light comes. An (3)____ body does not transmit light. Frosted

glass is called a (4)____ body because some light can get through it. (5)____ bodies give out (6) ____ of their own but most bodies are seen by (7)____ light. When a smooth body reflects light, the angle of (8)____ (9)____ the (10)____ of incidence. The (11)____ in a mirror is always the (12)____ distance (13)____ of the mirror as the object is in (14)____ of the mirror. Rough surfaces give a soft (15)____ light, while (16)____ surfaces tend to produce a glare if looked at from some (17)____. (18)____ mirrors can produce a real image. The slowing up of light after it passes into a more dense medium may cause it to (19)____ in a process called (20)____.

STORY TEST

Morris Has Some Practical Experiences with Light

Read carefully and critically. List all the errors and suggest corrections.

Last night about an hour before sunset I looked across a vacant lot to a greenhouse. At first I thought the place was on fire because there was such a glare of light. I decided however that I was seeing an image of the sun in each of the glass panes. Coming at the angle that it did, all the light was reflected and the glass acted like mirrors. After the sun had gone down, thunder clouds quickly shut off the twilight and it became very dark outside. I turned on the lights in the room. I turned to the window and looked in the direction of the greenhouse. I saw only objects that were in the room around me. The glass that had been transparent in the daylight had become opaque in the night and now acted as a perfect mirror. Out of doors everything was dark because it was in the shadow cast by the earth. A flash of light from my aquarium called my attention to my one gold fish I had put in the water a week before. As I neared the tank, I could see through the top surface and through one side. Imagine my surprise to see two gold fish, and stranger still, every time one moved the other one moved. I then looked straight down through the top surface but could find only one fish. I decided the optical illusion had been caused by the reflection of the fish by the surface of the water. So I had seen the real fish and his image in a mirror.

PROBLEM III. HOW ARE PHOTOGRAPHS MADE?

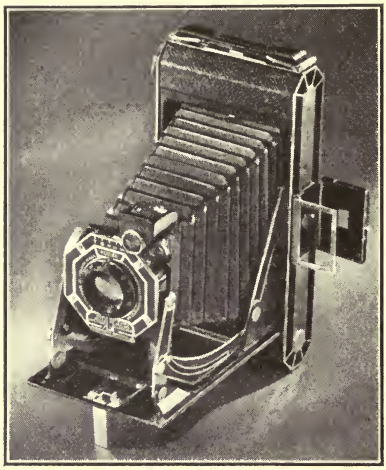
Have you ever seen among your family heirlooms a daguerreotype: an old-fashioned picture on a piece of tin set in a gilded frame? This old-type picture was the

forerunner of the great photographic industries of today. Think of the persistence of a man working on the idea that sunlight with the aid of a few chemicals could make a permanent picture. It took Daguerre fourteen years to work out his idea. Some others had devised processes by which a picture could be made if exposed for hours in a dazzling bright light. But that was not practical for photographing people. In 1839, Daguerre had perfected his process so that an exposure of a few minutes was sufficient to take the picture. These were made on a metal base and no duplicates could be printed from it. Today a fraction of a second only is needed to expose a plate or film and from the negatives any number of pictures can be printed. Such are the strides made by science in a few years. Today photography has become a leisure time activity for all, and the pages that follow will help you to enjoy this scientific pastime.

In the first portraits made with a camera the face had to be covered with white powder to reflect as much light as possible. The subject was then exposed to direct sunlight before the open camera for 30 minutes.

The Camera. We think of a camera as a light-tight box having a lens at one end and a place at the opposite end for a prepared photographic plate or film. But there is a simpler camera than that because pictures can be taken without a lens. In such a camera there is only a

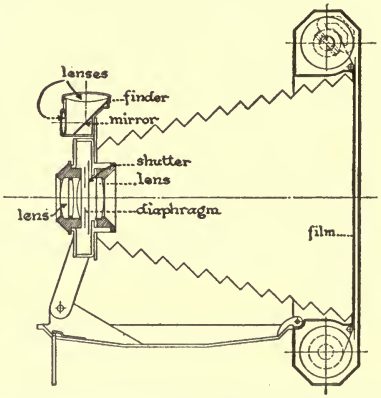
pinhole in the front end of a small box. Brightly lighted objects in front of the pinhole send light through it and an image is formed at the back of the box. If a film coated with chemicals sensitive to light is there to receive the image, the start of a photograph is made. The advantage of having a lens instead of the pinhole is that it produces a sharp image when the opening is large, thus permitting more light to enter. This shortens the time of exposure. With a pinhole camera any opening larger than a small pinhole [1] will make a blurred image. With a hole small enough to give a good sharp image, it will take from 10 to 20 minutes to make the exposure.



Eastman Kodak Co.

The camera used by amateur photographers.

The Diaphragm and Shutter. The lens camera has a diaphragm, the adjustment of which makes possible different sizes of opening through which light may enter. There is a shutter controlled to allow an exposure of a fraction of a second for a "snap shot" exposure or for a time exposure when



Can you tell the use of each of the parts of the camera named in the diagram?

[1] See page 162 for directions.

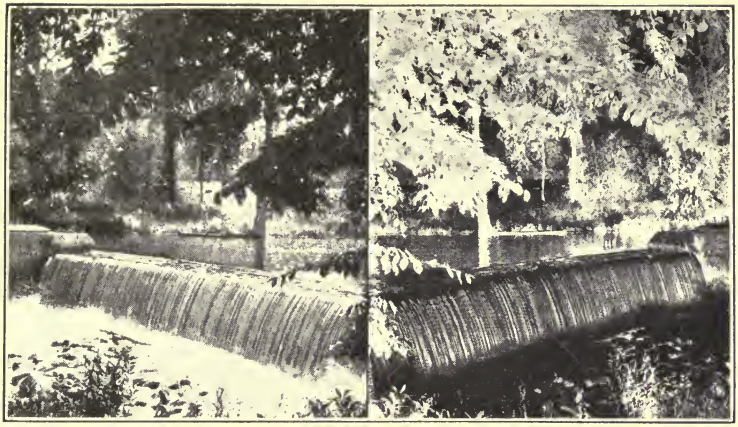
over a second is needed. The shutter and diaphragm are controls for the amount of light which is allowed to pass through the lens to produce the image on the film.

Lenses. If you can get two lenses of the same diameter but one thicker through the center than the other, you will be able to make an interesting experiment. If you are in a partly darkened room, light a lamp and hold the thick lens five or six feet from the lamp. Move a sheet of white paper back and forth on the side of the lens away from the light. You will soon find a place where a sharp image of the lamp appears on the paper. Now if you place another lamp a foot forward or back of the first and keep the paper still, you will see that objects at different distances give a fairly sharp image. If you repeat this with the thin lens, you will not be able to produce a sharp image of the two lamps when they are very far apart. The thick lens is a short-focus lens, and this is the type used in the box camera. You do not have to change the position of the lens or "focus" the camera because this is a "fixed focus" lens, that is, all objects in front of the lens and more than six feet distant will produce an image which is fairly sharp. Other cameras — the focusing type — use the long focus lens. For photographing near-by objects with such a lens the distance from the film must be adjusted according to the distance scale on the camera, but all objects over 100 feet away will give a sharp image when the lens is set at the 100 mark on the scale.

What Makes Some Cameras Expensive? You may have wondered why some people pay $50 to $100 for a special lens for a camera. They are paying for the speed of the lens. Only the central portion of the cheap lens can be used to give a sharp image. If the diaphragm is closed so that light enters through the center only, a longer time must be used for exposing the plate. The expensive lens is ground so carefully that the diaphragm may be

opened much wider and still give a sharp image. This lets more light in and shortens the exposure, and the lens is called "rapid." The cheap lens may give just as good a picture if you can give it sufficient time with the small opening.

Making a Negative. Many of you take pictures but give the films to a photographer to develop. If you do this, you lose half the fun. Why not learn to develop the films yourself? Most junior high schools have camera clubs and dark rooms, so you will have no difficulty in doing your own work. The plate or film is coated with gelatin containing silver bromide, a substance sensitive to light. When light from an object in front of the lens is focused on the film, it makes an image upon it which does not become visible until after the film is developed. Development takes place in a dark room which has only a red or ruby light in it. This light does not act upon the film during the short time required to change it into a negative. The film is first treated with a "developer," a chemical solution which causes a deposit of dark particles on the film. No dark deposit is made on those parts of the film not reached by the light. The differences of light and dark at any point is in proportion to the amount of light which acted upon the silver bromide. When development is complete, some silver bromide which was not acted upon by the light and which is still sensitive to it remains on the film. Before the film can be exposed safely to ordinary light, this silver bromide must be removed. A chemical salt, hyposulphite of soda, called "hypo," will dissolve the silver bromide and remove it from the film. This is used as a "fixing bath," because it makes the image permanent. After the film has been fixed, washed, and dried, the light and dark areas in it are just the reverse of those in the original picture and for this reason it is called a *negative.*



Which is the positive and which is the negative? How do the lights and shades in the negative compare with the lights and shades in the positive?

Making a Positive. The print is made by allowing white light to pass through the negative to a paper which is sensitive to light. Since less light will pass through the dark parts than through the light parts of the negative, the print will be just the reverse of the negative, or a *positive*, which has the same value of light and dark as the original objects photographed. Home printing is easy and is a fascinating pastime. Papers are of two types, those printed by artificial light and those printed by sunlight; the former require more time. Blueprint paper is one form of sun-printing paper; it is cheap and easy to handle since it can be developed in water without the use of chemicals.

Demonstration 2. Making a Print from a Negative.

Darken the room until you can barely see objects. Make up a developing bath by dissolving the powders in a tube of developer in water according to directions on the tube. Make a hypo ("fixing") bath by dissolving a tablespoonful of hypo (hyposulphite of soda) in half a pint of water. Arrange three trays or plates as follows:

Tray 1. Developer Tray 2. Cold water Tray 3. Hypo

You will need two squares of glass and two clothespins. Lay the negative dull side up on one piece of glass. Upon this lay a sheet of sensitized paper, smooth or coated side down upon the negative. Cover with the other piece of glass. Hold the two pieces of glass tightly together with the clothespins. Light a 100-watt lamp and hold the glass film side towards the light and 3 feet from it for 10 to 15 seconds. Extinguish the lamp. Remove the paper. Immerse the paper in the developer. If it comes up too black within 30 seconds, it had too much light; if it does not come up dark enough in 30 seconds, it needs longer exposure. A little experience will help you judge the time of exposure. After the picture has developed to the point you wish it, rinse quickly in water and place in the hypo. Move it around occasionally. After 15 minutes remove from the hypo and wash an hour in running cold water. Lay face down on a piece of cheesecloth stretched over a frame to dry.

With the directions just given you should soon become an expert amateur photographer. Why not organize a camera club if your school does not have one? You will be surprised how much this photography will help you in your science work, besides giving you and your friends a lot of fun.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order A word may be used more than once.

chemical	positive	fixed	camera
visible	negative	focus	image
diaphragm	neutral	opening	black
shutter	hypo	closed	light
developer	acid	dark	lens
results	recorded	red	sensitive

There are chemicals which are (1)____ to light. When these chemicals are held on the surface of a film or glass plate in a little gelatin and an (2)____ is thrown upon the film, a latent image is (3)____. When the film is developed, a picture with (4)____ and (5)____ parts reversed from what they were in the original view (6)____. After development, the film is (7)____ or made permanent in the (8)____ bath. The resulting film is called a (9)____; from this a (10)____ print is made. The (11)____ excludes (12)____ except when the (13)____ is open. The size of (14)____ to control the amount of light is regulated by the (15)____.

STORY TEST

ALBERT TELLS ABOUT HIS PINHOLE CAMERA

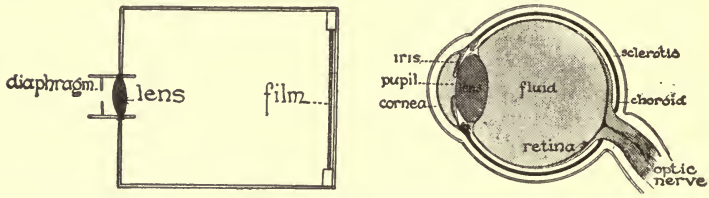
Read carefully and critically. List all the errors and suggest corrections.

This box I hold before you is a " pinhole " camera. I made a large hole in the front end of the box. Then I made a small hole in a piece of tinfoil with a needle and fastened this so-called pinhole over the hole in front of my box. I fastened a film in the back end of the box in a dark room, put the cover on, held my hand over the pinhole, and came out into the light. I placed the camera six feet from a bouquet of flowers which were in the sunlight. All of the rays of light given off by the flowers went through that tiny pinhole. They were bent as they went through and then made an image on the film. After covering the hole and returning to the dark room, I found the film had a picture of the flowers on it. To make this remain on the film, I developed the film in a solution called the developer. I washed the film and dried it in a lighted room because light cannot hurt it after development. After the film was dry, no picture was visible on it, but by printing on sensitive paper I could make a beautiful picture of the flowers. I haven't done this yet, but I know just how to do it. Place the paper on the film, coated sides together. Hold film towards the light. Then put paper into a hypo solution to fix it and to make the print permanent. Wash and dry.

PROBLEM IV. HOW DOES THE EYE RESEMBLE THE CAMERA?

We all know that the camera in its simplest form is a black, light-tight box containing a lens at one end and a place for a sensitive film at the other. Light is allowed to pass through the lens and is brought to a focus on the film. Here the picture is recorded on the film, which may be taken to a dark room and developed and made permanent. The human eye is like a camera in many ways, but it is much more delicate and complex. If we were to take a section through the human eye at right angles to the front of the face, we would see its likeness to the camera. Near the front of the eye is a transparent lens which throws a picture on a surface called the retina, at

the rear. The retina is connected to the brain by the optic nerve. The lens is capable of changing its shape,



What parts of the camera correspond to the parts of the eye?

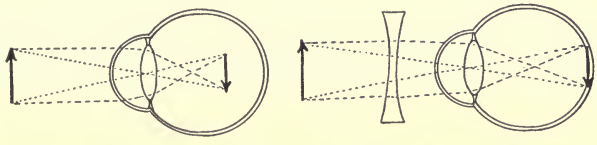
thus making it possible to focus the light and so make a real image of near or distant objects on the retina. This change of focus is called *accommodation*. A colorless fluid fills the space between the lens and the retina. The retina is the most wonderful part of the eye because it transfers the sensations produced by light in the eye to the brain by way of the optic nerve.

How the Eye Adapts Itself to Different Intensities of Light. The diaphragm in the camera changes the size of opening through which light may enter. The eye has a similar device, but it is called the iris. The black spot you see as the pupil of the eye is the opening through which light passes to the lens. If you go to the window when there is bright sunlight and look steadily at the sky for a moment, and then bring a mirror before your eye you will see that the size of the pupil or black hole in the colored iris is extremely small. If you turn quickly to a dark part of the room and look in the mirror, you will see the pupil grow larger as the iris adjusts itself to the

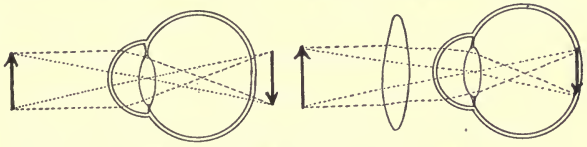
How does the eye adjust itself to different intensities of light? Which of the two eyes is looking into a bright light? How do you know?

smaller amount of light. This change in the size of the pupil is automatic. The eye cannot stand looking into very strong light, nor into a glare, in spite of this adjustment. The iris cannot contract enough to shut out the intense light without also making it difficult to see objects or printed matter. We should therefore avoid straining the eyes by trying to work or read with a bright or glaring light within our field of vision.

Some Eye Defects. In spite of the wonderful mechanism that it is, the eye often has slight defects. The most



use a concave lens to correct nearsightedness



use a convex lens to correct farsightedness

common one is astigmatism, due to a slight uneven curvature of the lens or the cornea. This difficulty is a frequent cause of headaches, and should be attended to by an oculist.

Another defect is nearsightedness. In this case the eyeball is too long from front to back or the lens too thick, so that the image of distant objects is brought to a focus before reaching the retina. If you have to hold your book close to your eyes, and if you squint when looking at things, you should go to an oculist and have your eyes tested for glasses, as nearsightedness can quickly be corrected by this means.

What can you say about the light here? Have you any suggestions to offer?

Farsightedness is a defect in which the eyeball is too short or the lens too thin and the image of near objects is focused behind the retina. This defect is more difficult to detect and is also the cause of many headaches. Properly shaped lenses will remedy both nearsightedness and farsightedness by bending the light rays so that they focus properly by means of refraction.

Care of the Eyes. Some good rules for care of the eyes are these:

1. Avoid direct glare or reflection from paper, books, or highly polished surfaces.
2. Do not sit facing strong light.
3. Do not sit so that your shadow falls on your work.
4. Do not read or work by a flickering light.
5. Do not read on trains or motor cars.
6. Adjust the intensity of light to your needs. Strong light is needed for fine print.

7. Do not use the eyes when they ache or when you are fatigued. Remember that your eyes are the most valuable asset you have. Never abuse them. If tired, a wash of boric acid will help. Do not use any patented drops as they may contain dangerous poisons, and usually you buy only boric acid and salt, which you could mix yourself. Above all, consult a reliable oculist or eye specialist in case your eyes need attention.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange them in proper numerical order. A word may be used more than once.

front	reading	image	automatically
back	cornea	bend	accommodation
side	iris	decreases	glasses
lens	retina	increases	shaped
mirror	pupil	curvature	astigmatism
harmful	light	focus	enters
beneficial	diaphragm	inverted	farsightedness

It is the (1)____ of the eye that produces an (2)____ on the (3)____. The amount of light which (4)____ the eye is regulated by the (5)____ which (6)____ and (7)____ the size of the (8)____. It is very (9)____ to have light directly in (10)____ of one when (11)____. Uneven (12)____ of the (13)____ or of the (14)____ may cause (15)____. In nearsightedness the image is in (16)____ and in farsightedness the image is in (17)____ of the retina. (18)____ to correct these defects may be (19)____, so that they bend the rays of light to make them (20)____ properly.

STORY TEST

Beulah's Father Is an Oculist

Read carefully and critically. List all the errors and suggest corrections.

My father is an oculist and fits people with glasses. I have an uncle who is an optometrist; he treats diseases of the eye. So you see I am just the one to talk to you about the human eye. In the first place the eye is rounded or ball-shaped; this makes it

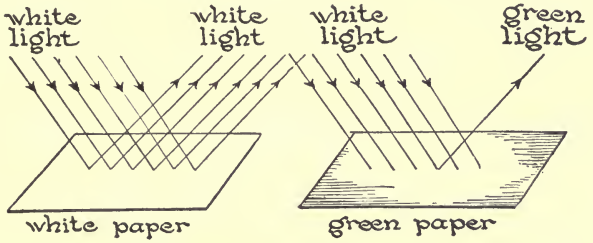
act upon light like a lens. When light from an object passes through the eye, it forms an unreal or virtual image on the cornea. The position where an image is formed depends upon the distance the object is from the eye. However, the eyeball can change its shape and move the back surface of the eye nearer or farther away from the pupil. This is taken care of automatically so that in the normal eye there will always be a clear image formed. This adjustment is called accommodation. Father says most people wear glasses to remedy eye defects but some wear them for " looks."

PROBLEM V. WHAT IS COLOR?

What Is White Light? If you pass sunlight through a triangular piece of glass called a prism, the white light is separated into the following colors: red, orange, yellow, green, blue, and violet. The waves of all these colors differ in length. The longest wave affecting sight gives us the color red, the shortest, violet. Color, then, is a property of light which depends upon its wave length. When light is refracted, the blue rays are bent more than the red rays, or the shorter the wave length, the more it is bent. The prism bends the beam of light twice in the same direction, once as it enters the glass and again as it leaves the glass and enters the air. Both times it separates the colors and so produces a band of colors on a screen. This band of colors is called the "*solar spectrum.*" The rainbow is caused by light being broken up into these colors by bending or refraction in falling raindrops. When all the different wave lengths from the sun are mixed together, white light is produced. White substances are those which reflect all wave lengths, hence all colors, while black substances are those which absorb all wave lengths of light.

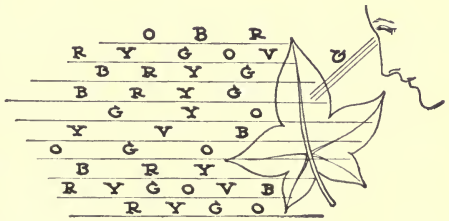
Why does a prism separate sunlight into colors?

Colored Objects. A red body absorbs all the wave lengths except those producing the sensation of red. A

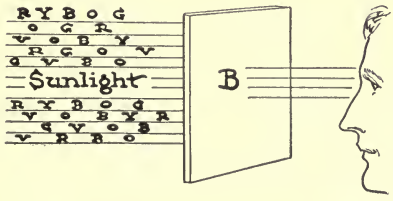


Why is such a small part of the light falling upon the green paper reflected?

blue body absorbs all the wave lengths except those producing a sensation of blue. Make a blue spot on white paper and an orange spot a few inches from it and then look at the two colors by means of a glass plate held vertically between them so that one spot is seen by transmitted light and the other by reflected light. A grayish white spot will result. Any two colors which when mixed give a sensation of white or gray are complementary colors. Red glass absorbs all rays except those producing red, hence a blue dress if viewed in a room having red window glass would appear black. This is due to the fact that no blue comes in to be reflected and the dress absorbs the red. Every color except red would appear black when viewed in a red light.

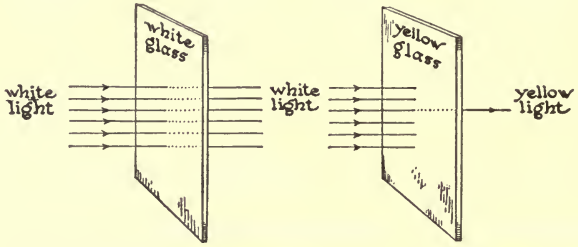


What is the color of this leaf?



What is the color of the piece of glass?

Mixing Pigments. Mixing pigments such as paints or dyes is quite a different matter from mixing colored lights or light rays. If you mix blue and yellow paint,



Why do only yellow rays appear at the right of this diagram?

green will result. A yellow pigment absorbs all the spectrum colors except yellow and green, while blue pigments absorb all the spectrum colors except blue and green. Green is the only color reflected by both pigments, and is therefore the only color seen when the two are mixed.

Color Blindness. In order to drive a locomotive, the engineer must be tested for color blindness. There are about three to four per cent of boys and about one per cent of girls who cannot distinguish certain colors. They are color blind. The most common form of color blindness is the inability to distinguish between red and green.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

wave	darkness	neutral	absorbs
waves	red	normal	yellow
reflects	green	violet	pigments
light	blue	white	sensations
colors	property	black	supplementary
complementary	refracts	length	length

Color is a (1)____ of (2)____ which is determined by its (3)____ length. The shortest (4)____ (5)____ gives the sensation of

(6)____ and the longest produces the sensation of (7)____. All (8)____ produced in the sun mixed together give (9)____. Any two colors which when mixed produce white are (10)____ colors. Blue and yellow (11)____ when mixed produce (12)____. If you look at a red book through blue glass, it will appear (13)____ because the glass transmits only (14)____ and the book (15)____ blue.

STORY TEST

Harriet Reports upon Her Experiments

Read carefully and critically. List all the errors and suggest corrections.

Having an uncle who is a glass maker, I teased him to make me three prisms; one of white glass, one red, and the third green. I used these in a dark room into which a beam of sunlight came through a small hole in the shutter. I had a screen of white paper, one of black paper, one of green, and wore a red dress. When I held the white glass in the beam of sunlight to form the solar spectrum, the colors could be seen upon the white screen. When thrown upon my red dress, the whole beam was changed to red. When thrown upon the green screen, I saw only a small green band of color. I then took the red prism and made a spectrum of all colors on the white screen. When thrown on the red dress, the red was absorbed and all the other colors were seen. Then I used the green glass. When the black paper was held in position, there was just a narrow green band of color upon it, but it showed a red band when the beam was directed to the red dress. The green screen showed a green color and the white screen showed all the spectrum colors.

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. The generalizations that can be made on this unit are numerous. You may change the list that follows if you so desire, as this is only giving you a partial list of those that you might make for your review summary.

1. Light travels with greater speed than anything else.
2. Light travels in straight lines.
3. Light rays may be bent by reflection or by refraction.
4. Light produces chemical changes of much value to man.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of the statements you believe to be incorrect. Your grade = right answers* $\times 2\frac{1}{2}$.

I. **Light travels:** (1) in straight lines; (2) through translucent bodies; (3) 1100 feet per second; (4) more slowly through water than through air.

II. **A real image may be produced:** (5) by a plane mirror; (6) by a piece of plate glass; (7) by a pinhole camera; (8) by a concave mirror.

III. **A beam of light will be bent (refracted) when it goes from:** (9) air into glass at a 90° angle to the surface; (10) air to glass at a 30° angle; (11) water into air at right angles to the surface; (12) water into air at an angle of 60° between the ray and the surface of the water.

IV. **The ordinary camera lens produces a real image on the film because the lens:** (13) reflects the light from the object; (14) refracts the light coming into it; (15) sifts or filters out the objectionable rays of light which would mar the image; (16) permits light from the object to reach the film.

V. **When a beam of light from candle flame comes to a piece of plate glass at right angles to the surface, some of the light:** (17) is refracted; (18) is reflected; (19) is changed to a gas; (20) is transmitted.

VI. **The image of an object in a plane mirror is:** (21) larger than the object; (22) unreal; (23) the same distance back of the mirror that the object is in front of the mirror; (24) inverted.

VII. **Concave mirrors:** (25) may produce real images; (26) are used in some telescopes; (27) are used in cameras; (28) are used in automobiles to watch traffic in the rear.

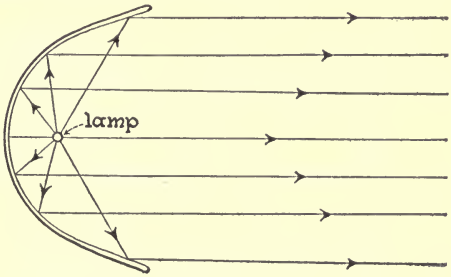
VIII. **You are on one side of a stream of quiet water and see a large oak tree on the other side. The sun shines brightly and lights up the side of a tree towards you:** (29) you see a real image of the tree in the water; (30) there is also a shadow of the tree on the water; (31) as you see the image, the tree appears upside down; (32) the image is unreal.

IX. **The eye "focuses" or makes the image on the retina clear by:** (33) changing the distance between the retina and lens; (34) changing the thickness of the lens; (35) changing the size of the pupil; (36) by a process called "accommodation."

X. **A blue dress appears blue in daylight because:** (37) the material absorbs only blue light from the sunlight; (38) the material absorbs all the sunlight except blue; (39) its own color added to sunlight gives blue; (40) it gives out blue color of its own which is stronger than the white of sunlight.

THOUGHT QUESTIONS

1. Why are lamp shades made of opal glass?
2. Why are electric light bulbs frosted?
3. Why are offices in large buildings often inclosed in translucent glass?
4. Make a list of the objects you saw on your way to school that showed regular reflection.
5. How would you point a stick to a given point at the bottom of a dish of water if your stick has to enter the water at an acute angle?
6. Compare a real and an unreal image and show how you would make each.
7. Why do the reflectors used for automobile headlights have the shape shown in the illustration?



8. Why is the image seen in the back of a camera inverted but that seen in the finder upright?
9. What happens to a beam of bright sunlight by which you see the white sand on the beach: first without glasses and later through amber sun glasses?
10. Why is it difficult for you to write your name while looking at your hand, pencil, and paper only in the mirror?

11. How can you adjust your desk study light to give you efficient lighting?

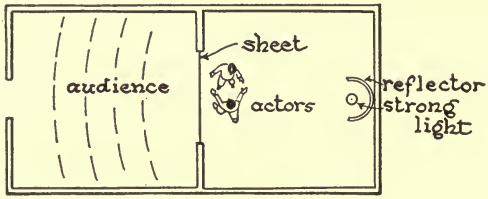
REPORTS UPON WHAT I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
   a. The importance of transparent glass.
   b. Colors in the sky.
   c. An automobile headlight.
   d. The eyes of man and of insects.

SCIENCE RECREATION

1. Fun with Shadows

Hang a sheet to cover a doorway. Have the audience in a darkened room. In the other room have one very strong light.

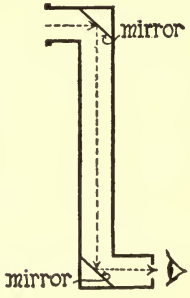


Make pantomime shadow pictures by acting between the light and the screen. Plan a shadow play.

2. An "Anglescope"

Sometimes you like to watch a person without his suspecting it. You can apparently be looking through a tube in one direction,

but really see what is going on at one side. The diagram will suggest how to place a mirror in a mailing tube having a hole cut in the side.



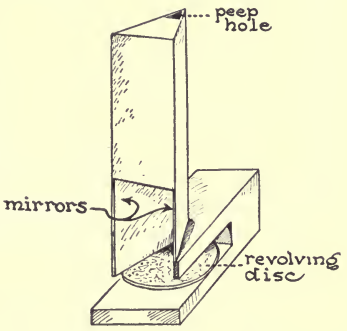
3. Make a Periscope

Secure a long mailing tube about 2 inches in diameter and two small mirrors (2 for a nickel

at the 5 and 10). Cut holes near the ends of mailing tube but on opposite sides. Fasten the mirrors back of these openings facing and parallel to each other but at angles of 45° to the long axis of the tube. Then objects in front of the top opening can be seen by looking into the lower opening.

4. A Home-Made Kaleidoscope

Fasten two strips of mirrors about 2″ × 7″ or 8″ together with the mirror fronts facing each other at an angle of 45°. A tin frame can be bent so it will hold there. Cover one end halfway across, leaving a peep hole where the two glasses meet. Cover the wide open space two inches from the end. Support this vertically with the peep hole at the top above a block of wood, leaving a space under it where a disc can be placed so it can be revolved under the two mirrors. By placing colored chips of glass and other objects upon the disc, different patterns and designs may readily be produced.



5. Make a Scrapbook on Light

Collect pictures and clippings from newspapers and magazines. Group the clippings according to subject matter.

SCIENCE CLUB ACTIVITIES

1. Test for Color Blindness

Buy or borrow a set of Holmgren's woolens for testing color blindness. Test the eyes of each member of the club.

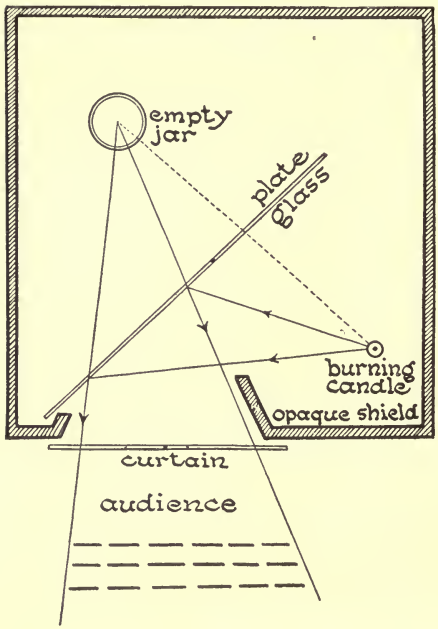
2. Making a Picture

Get some one who knows how to demonstrate the use of a camera with a ground-glass back, also how to print and finish a picture from a negative.

3. Burning a Candle in a Jar of Water

Arrange your apparatus as in the diagram on page 162. The plate glass should be 15 to 24 inches by 3 to 4 feet. Double-thickness glass may be substituted. The jar of water is seen by transmitted light, and the candle by reflected light. Have the

candle burning and jar empty at the start. Pour water slowly into the jar. Your audience expects the candle to burn until the water reaches the wick, but it continues to burn until they see the water well above the top of the flame. If the jar of water is shown by reflection, hold the candle where the audience can see it. Have the match ready. Have the curtain closed while you " place the candle in the jar of water and light it." You have the proper spot marked on the table where you place the candle. After lighting it, have the curtain drawn aside and the audience sees the candle burning in the jar of water. Test the positions before the audience arrives.



4. Make a Pinhole Camera and Take a Photograph with It

A small prize may be offered for the best picture made by a member of the club. A pinhole camera may be made in the following way. Use a box about five inches square and three inches deep. It must have a cover which slides down over the box for a depth of at least one inch. The interior must be painted black and made light-tight. Cut a hole one half inch in diameter in the middle of one side or end of the box. Paste a piece of tinfoil on the inside of the box over the hole. Make a pinhole in the center of this tinfoil. The success of your picture depends on the care with which you make this hole. The best results are obtained when the diameter of the pinhole is in proportion to the square root of the distance from the pinhole to the plate.[1]

[1] Use the following formula:

$$\text{Diameter of pinhole} = K\sqrt{\text{Distance of plate from pinhole}}$$
$$K = .0008$$

This diameter may be measured by some machinist or science in-

Paste cardboard strips on the inside of cover to hold the sensitized plate.

The picture is made on a glass plate which is held in place by narrow strips of cardboard glued in along the vertical edges of the plate. This plate is to be put into the camera while in a dark room. Of course, the pinhole should be kept covered until you reach the object you wish to photograph and covered again after the picture is taken. The exposure, depending on the light, should be from ten to twenty minutes.

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Compton's Pictured Encyclopedia.
Bragg, Sir William, *The Universe of Light.* Macmillan, 1933.
Dull, C. E., *Modern Physics.* Holt, 1929. Page 404–498.
Houston, E. J., *The Wonder Book of Light.* W. and R. Chambers, Ltd.
Luckiesh, M., *Artificial Light.* Century, 1920.
Meister, M., *Energy and Power.* Scribner's, 1930.
Whitman, W. G., *Household Physics.* Wiley and Sons, 1932. Principles of Light, pages 272–290; Natural Light, pages 292–308; Artificial Light, pages 310–321; Illumination, pages 322–342.

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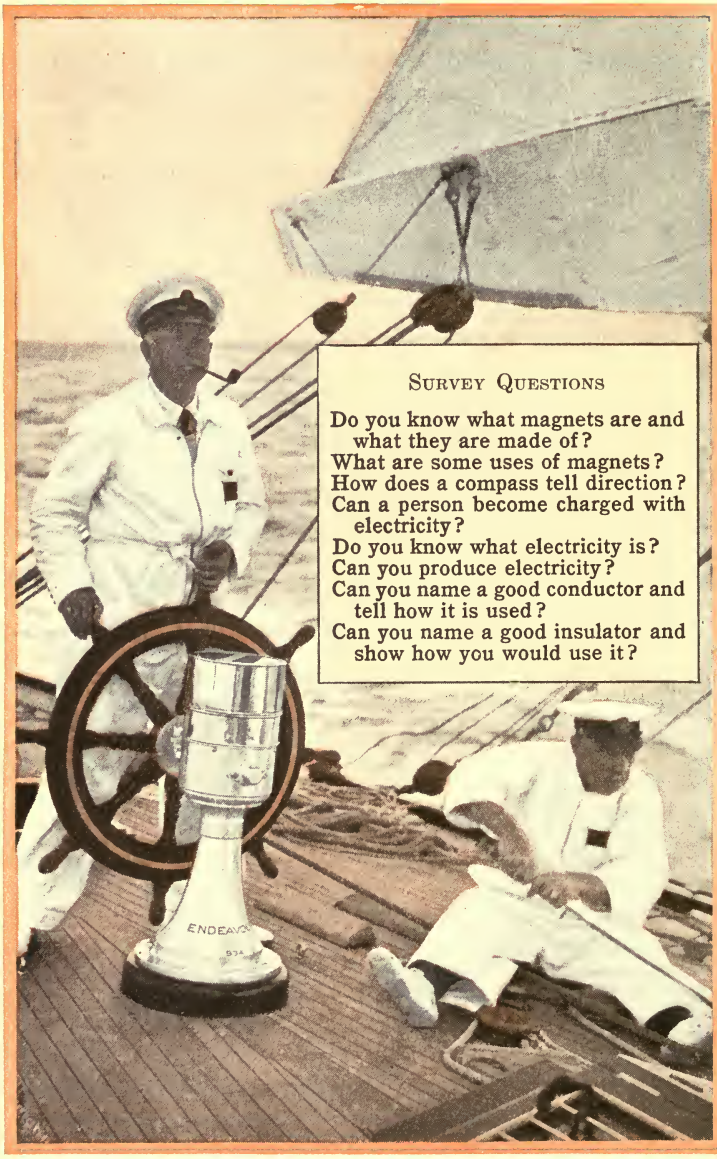
structor who has a micrometer caliper, with which to measure the needle so you can make the hole just the right diameter.

Having obtained a needle of the right diameter, do not force it all at once into the tinfoil, but push it in slowly, first on the one side, and then on the other so as not to tear the foil. When you have made the hole, be sure to smooth off the edges, as a clear picture cannot be made unless you have a clean cut hole.



Survey Questions

Do you know what magnets are and what they are made of?
What are some uses of magnets?
How does a compass tell direction?
Can a person become charged with electricity?
Do you know what electricity is?
Can you produce electricity?
Can you name a good conductor and tell how it is used?
Can you name a good insulator and show how you would use it?

Edwin Levick

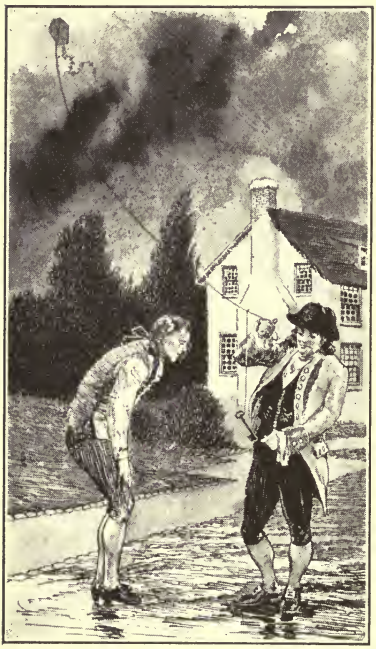
UNIT VII

HOW WE MAY PRODUCE ELECTRICITY AND MAGNETISM

PREVIEW

Long before the birth of Christ, it was known that a certain kind of iron ore which came from Magnesia in Asia Minor had the property of attracting other small bits of iron. To this ore, the name of magnetite was given, from which we get our word "magnet." Early peoples called these stones "lodestones" or leading stones, and thought they had magical powers. Although these magical stones were known to the Greeks 600 years before Christ, the Chinese are credited with having made the first practical use of magnets, for they discovered that a lodestone if it floated on a block of wood in water always pointed in a north-south direction. This discovery paved the way for the development of the mariner's compass in Europe in about the eleventh century. Thus it was that the magical lodestone enabled adventurous sailors and explorers like Columbus to sail away out of sight of land to discover new lands. In 1576 it was discovered that a compass needle properly supported would dip toward the poles of the earth unless one were on the equator. This caused William Gilbert in 1600 to conclude that the earth acts as a great magnet and attracts compass needles more strongly in some places than in others. Later still, in 1831, the arctic explorer, Ross, discovered a magnetic pole 1200 miles south of the north pole of the earth.

The influence of the earth's magnetism extends far out into space, and may be one cause of the displays of "northern lights" or aurora seen in the sky of the northern and southern hemispheres. You have all heard of "sun spots." While we do not know just what they are, scientists find that the activity of sun spots is closely associated with the magnetic activity on the earth.

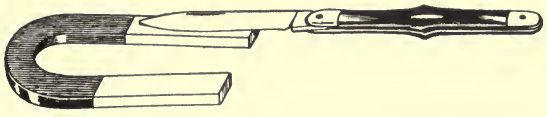


Franklin took chances with his kite, but he discovered that electricity could be conducted through the wet kite string. What danger did he expose himself to?

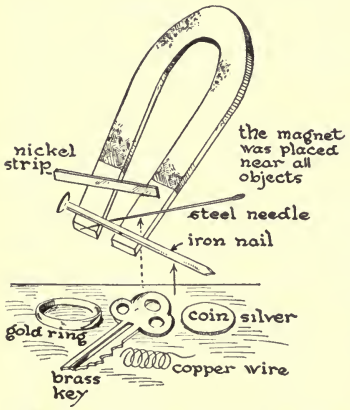
There are many interesting facts which we can piece together in telling the story of how electricity has been harnessed and has become the most powerful of man's servants. The Greeks learned of one property of electricity when they rubbed amber, which they called electron, and found that it would pick up small particles. When Franklin sailed his kite in a thunderstorm and discovered that lightning was a form of electricity, another step was taken. And when Galvani, the Italian scientist, found that the legs of dead frogs twitched when he brought them into a circuit with iron and copper, still another important fact about electricity was discovered. Then came Volta with his discovery that electricity could be generated by chemical means. We might go through a long list of discoveries, each of which gave us more and more knowledge about electricity.

PROBLEM I. WHAT CAN MAGNETS DO?

People have not always depended on lodestones for magnets. It was discovered long ago that magnets could be made out of steel by rubbing the steel with another magnet. You can make a small magnet yourself. If you stroke a needle from the middle to the point several times with one end of a magnet and then, using the other end of the magnet, stroke it from the middle to the opposite end, you will make a magnet of the needle. You can make a magnet of any piece of steel in the same way. Large powerful magnets are made by passing a current of electricity through wires which surround iron or steel cores.



How will this change the properties of the knife blade?

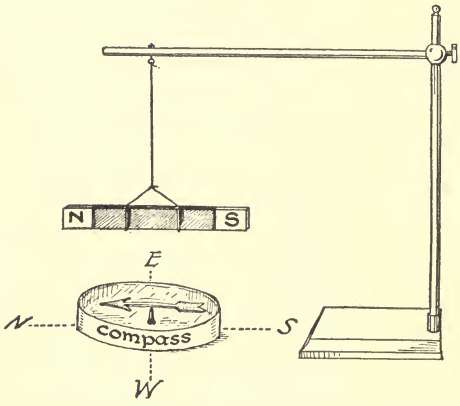


What substances will a magnet pick up?

What Will a Magnet Attract? If we lay steel needles, pins, tacks, gold pins, silver pins, pure nickel, a nickel coin, a copper coin, and a brass key on the table and move a bar magnet slowly over them, will anything happen? What substances are picked up? We see as a result of this experiment that a magnet will not pick up all metals. It has been found that magnets will attract iron, steel, pure nickel, and cobalt, but will not attract any other common substances.

Permanent and Temporary Magnets. If you place a powerful bar magnet over a dish of iron nails, you will

find that they cling to each other as well as to the magnet. If you separate the magnet from the nails which are touching it, all the nails will immediately cease clinging to each other. Magnetized nails may cause other objects such as soft iron or tacks to become magnetized for a time, but as soon as they are loosened from the permanent magnet, they lose their magnetic properties. Even permanent magnets may lose their power after a while, especially if they are heated. Permanent magnets are made of steel or of some alloys of steel; temporary magnets are made of soft iron.



Can a bar magnet be substituted for a compass?

What Happens to a Suspended Magnet? Take a long bar magnet and suspend it by an untwisted string so that it can swing in a horizontal plane. It will take a position in a north-south line. We may check this with a compass. That end of the magnet pointing north is called the north-seeking or north pole, and the other end is called the south-seeking or south pole of the magnet. Since all magnets have this property, a magnetic needle is used in the mariner's compass.

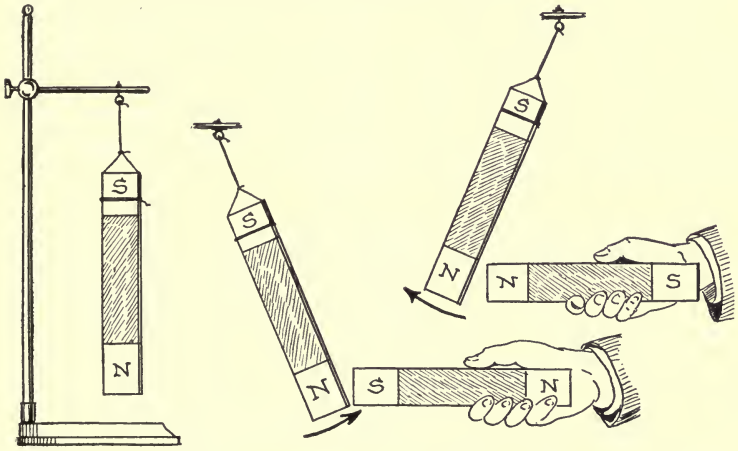
How to Make a Compass. Magnetize a needle by rubbing it on a bar magnet. Cut off a thin sheet of cork and float the cork in a dish of water. Lay this magnetized needle on the cork. What position does it take? Put a needle that is not magnetized on the cork. Does it act in the same way? How could you find east and west if you had a compass?

How to Use a Compass. In the pocket compass the needle is free to move over a disk on which the points of the compass are printed. If the compass is put down flat, the needle of the compass will move to and fro until it finally points to the magnetic north. If now the disk of the compass is shifted so that the N on the disk is just under the needle, all compass directions will be shown approximately correct.

Demonstration 1. To Determine the Laws of Magnetic Poles.

(*a*) *Do both poles of a magnet attract magnetic substances?* Bring the north pole of a bar magnet into a pile of iron tacks. Test the south pole in the same way. Test the center of the bar. Compare results. Do both poles of the magnet attract a magnetic substance? Does the equator of the magnet show strong attraction?

(*b*) *Relation of magnetic poles to each other.* Suspend a bar magnet vertically, N-pole down. Bring the south pole of a bar magnet near the north pole of the suspended magnet. Bring the north pole of the bar magnet near the north pole; then near the south pole. What are the results in each case? Make a statement concerning the attraction and repulsion of magnetic poles.



Demonstration 2. To Magnetize a Steel Sewing Needle.

Drop the magnetized needle (p. 167) into iron filings on a sheet of paper. Move the needle around and pick it up. Where do the filings cling?

Are there many at the ends or in the middle? Clean off the filings and break the needle into two parts. Place these in the filings. What happens?

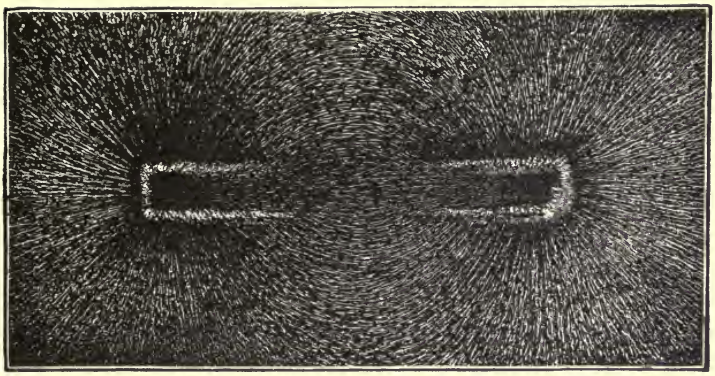
How the Magnetic Poles Act. These experiments show us that not only do magnets attract certain metals, but that if a magnet is cut in two parts, it will continue to be magnetized. We notice that the greatest attractive force is nearest the ends of the magnet. If we bring the north pole of one magnet near the north pole of a suspended magnet, the north pole of the latter moves away. If we bring the south pole of a fixed magnet to the north pole of a movable one, the south pole is drawn toward the north. This always occurs when two magnets are brought together and gives a law which we may state as follows:

Like magnetic poles always repel, and unlike magnetic poles always attract each other.

Demonstration 3. To Show the Magnetic Field.

Place a bar magnet under a piece of white paper with a strip of board of the same thickness on each side of it. Now shake iron filings evenly over the paper. Tap the paper gently. Notice what happens to the filings. Where are they most numerous? How can you describe their arrangement on the paper? Make a diagram of the magnet and of the lines of filings. How do they compare with the illustration on page 171?

A Magnet Influences Space around It. Tacks or iron filings will jump across the air space to a strong magnet. A compass needle will turn when several feet away from a strong magnet. These facts indicate that the influence of the magnet extends in all directions from the magnet. This force decreases as the distance increases. The space about the magnet in which this magnetic influence exists is called a *magnetic field.* If a compass is placed in a magnetic field, the needle will take the direction of the lines of magnetic force. These lines are considered as



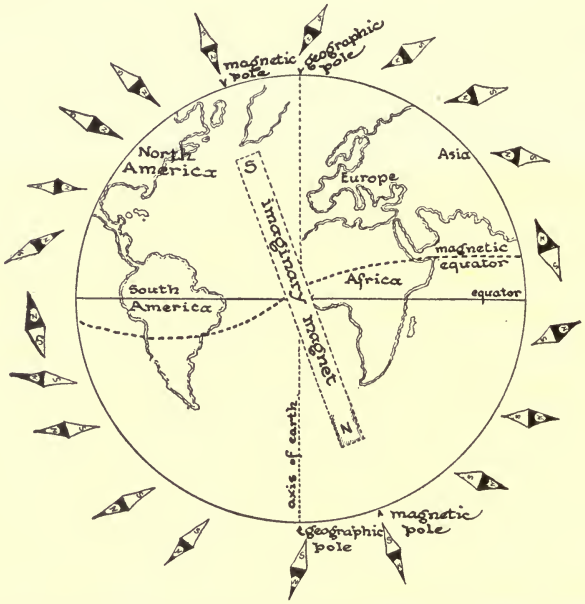
The magnetic field around a bar magnet.

coming out of the north pole, circling around, and entering the south pole of the magnet. The magnetic field is seen clearly in the illustration above.

The Earth as a Magnet. If you had a magnet mounted on a horizontal axis and you traveled with it from New York over Canada toward Hudson Bay, you would find that the compass needle pointed a little west of north, and, as you went farther north, it would dip more and more toward the perpendicular. If you were explorers, you would find a place north of Hudson Bay where the compass would point down toward the center of the earth. This is the magnetic pole in our northern hemisphere. A similar magnetic pole exists in the southern hemisphere. These magnetic poles are each a good many hundred miles away from the geographic pole where the earth rotates on its axis. The earth, being a magnet, is surrounded by magnetic lines of force. It is because of these lines of force that the compass acts as it does.

Value of the Compass. We only have to think of the pilot on sailing vessels or steamers shut in by a dense fog, or of aviators flying blind, to realize the great value of the compass in modern life. For many years the great steamships depended largely upon the magnetic compass.

Now they use a gyro-compass which is not magnetic and which is superior to the old type. When Lindbergh made his astonishing solo flight, he was able to put his ship down on the field near Paris because he had worked out his course exactly and had used the magnetic compass in doing this.



Can you tell why a dipping compass needle would turn completely over if carried around the earth through the poles?

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

brass	magnetic	surrounded	field
iron	magnetized	filled	earth
steel	wood	poles	attract
silver	non-magnetic	water	repel
hard	lines	equator	force
soft	surfaces	through	plane
center (middle)	opposite	passes	compass

Magnets made of (1)____ keep their strength much longer than those made of (2)____ iron. A knife blade can be (3)____ by stroking each half from the (4)____ with the (5)____ ends of a strong magnet. Every magnet is (6)____ by a magnetic (7)____ which is filled with (8)____ of magnetic (9)____. Like magnetic (10)____ (11)____ but unlike (12)____ poles (13)____ each other. The needle of the magnetic compass takes the direction of the (14)____ lines of (15)____ of the (16)____. Magnetism (17)____ through (18)____ which are (19)____, such as glass, copper, and wood. A magnet will attract only (20)____ substances.

STORY TEST

RALPH GIVES HIS OBSERVATIONS ON MAGNETS

Read carefully and critically. List all the errors and suggest corrections.

They make very powerful magnets out of an alloy of steel, nickel, and cobalt. Nickel is not a magnetic substance because when I tried to lift a 5¢ piece with a magnet it was not attracted. I saw two of these powerful magnets demonstrated. When the two magnets were laid on the table with unlike poles together and released they pushed apart because like poles repel. One magnet would hold the other in the air above it when guides were placed so that the top magnet could move only vertically and the north pole of one was placed on the south pole of the other. The magnetic field was so strong that when a compass was placed 8 inches away from the middle of the magnet the needle took a position parallel to the magnet with its poles pointing in the same direction as those of the magnet. When one end of a bar of copper was placed in iron filings and the upper end of the copper touched with the magnet the copper became a temporary magnet and when lifted iron filings clung to it. I saw a magnet held horizontally, lowered into a pan of iron filings and lifted. The largest mass of iron filings was near the middle of the magnet because that is the place where the magnetic force is concentrated. If a magnet is cut in two at its center, the lines of force within the magnet will be cut off and all the magnetism destroyed.

PROBLEM II. WHAT ARE SOME WAYS OF PRODUCING ELECTRICITY?

You have sometimes made an electric spark when you "scuffed" your feet over the carpet in winter or rubbed the cat's fur the wrong way, or when your hair stood up

LUIGI GALVANI, 1737–1798.

YOUNG Galvani was a native of Bologna, Italy. Born of good family, he was early destined for the church, but changed to the profession of medicine. Later he became a professor in the University of Bologna, where he became famous for his research work. He had always been interested in the nervous system and wondered why nerves responded to stimulation. A chance twitching of the leg of a frog he was experimenting with gave him the clew for which he was looking. He found that when a moist frog's leg was touched by two unlike metals it would twitch. Until the time of Galvani no one had ever suspected the presence of a current of electricity, although many experiments had been made with static or frictional electricity, and people knew a good deal about magnets.

Galvani thought the movement of the frog's leg was due to an electric fluid in this muscle, but a little later Volta, a professor in the near-by University of Padua, proved that Galvani was wrong. He showed that the electric current was due to chemical action taking place between the two unlike metals connected by the moist frog muscle. This made electricity on the same principle as it is made in our galvanic batteries today, and made possible the flashlight, our electric doorbells, and the hundreds of devices we use today that depend upon the electric battery.

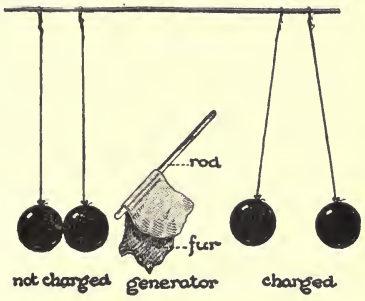
in an astonishing manner when you brushed it. When the air is cold and dry, a hard rubber fountain pen or a rubber comb rubbed briskly with flannel will attract small bits of paper or a pith ball supported by a thread. If the ball or the bits of paper become electrified, as they sometimes will after clinging to the rubber for a moment, they will be repelled and fly away from it. The hard rubber was charged with electricity by friction. The objects which touched the charged rod were electrified by contact.

Demonstration 4. Properties of Electrified Bodies.

You will need these materials: two large rubber balloons, string, silk cloth, fur, glass rod, and a hard rubber rod. Fasten a string across the room near the ceiling. Blow up two large rubber balloons until they are tight. Fasten them on strings looped over the ceiling string. Make them at a height level with your head and six inches apart.

A. Rub one of the balloons with fur. Is there any action now between the two balloons? Between the balloon rubbed and your hand held near it?

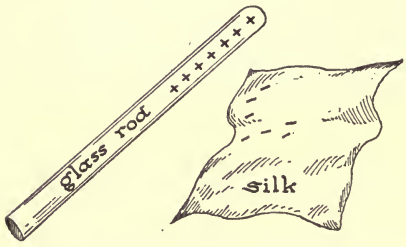
B. Arrange the balloons so that when neither is charged, they hang just touching each other. Rub both the balloons with fur. After you rub one do not let it touch anything until the second one is rubbed. Release the two. What happens? Compare this result with the one when only one was rubbed.



C. Separate the two balloons so that you can use one without interference from the other. Charge the balloon by rubbing it with fur. Rub the hard rubber rod with fur. Bring rod near the balloon. Rub the glass rod with silk. Bring the glass rod near the balloon. What was the action between the hard rubber rod and the balloon? Between the glass rod and the balloon?

Conclusion and Explanation. At first the bodies were neutral. After being rubbed they were charged with electricity. Does a charged body attract an uncharged or neutral body? Do two of the charged bodies attract each other? Repel each other? Do all charged bodies have the same properties?

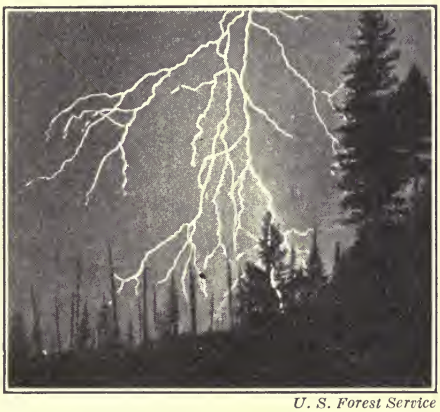
Charged Bodies. In this experiment we learned that when a hard rubber rod is rubbed with fur, the rod repels a rubber balloon which had previously been rubbed with fur. But a glass rod rubbed with silk attracted the balloon. Evidently there are two kinds of electric charges. According to our present theory of matter, each neutral atom is composed of a positive nucleus or central portion. The particles which make it positive are called *protons*. Negative particles of electricity called *electrons* are believed to revolve around the nucleus. The atom is normally made up of equal numbers of protons and electrons, the former being entirely inside the nucleus. There is a strong attraction between the protons in the nucleus and the electrons, but some of the electrons can be separated from the outer part of the atom. Protons never leave the atom to go into another body. When we rubbed the glass and silk together, some of the electrons were transferred from the glass to the silk. This makes the silk negative. The glass rubbed with silk having lost electrons now has more protons than electrons and so it is positively electrified. When hard rubber is rubbed with fur, electrons go from the fur into the hard rubber, making the fur positively electrified and the hard rubber negatively electrified. Whenever electrification is produced by friction between two bodies, the positive charge produced in one equals in amount the negative produced in the other. It was Benjamin Franklin who first suggested the names positive and negative for these two kinds of electrification. From these experiments we can make the general statement



Where did the electrons shown on the silk come from?

that *two bodies with like charges repel each other,* while *two bodies with unlike charges attract each other* and *a body with either charge will attract a neutral body.*

Conductors and Insulators. Soon after 1600, men tried to electrify many substances. They decided that metals could not be electrified. In trying to electrify a metal, they held it in one hand and rubbed it with fur, silk, or flannel, and in no case did they get any result. It was not until after 1700 that some one held a stick of dry wood which had a metal on its end and rubbed the metal with fur. The metal received a charge of electricity which was easily detected. In earlier trials all the electricity produced in the metal by rubbing was given off or conducted from the metal to the hand which in turn conducted it away. This experiment showed that in relation to electricity, bodies are separated into two classes, *conductors* and *nonconductors* or *insulators.* It was this property of some materials to conduct electricity that gave Benjamin Franklin the opportunity to get sparks from his kite string during the thunderstorm, and suggested to him that lightning rods would protect buildings by carrying up streams of electricity from the earth to the cloud above, or from the cloud down to the earth. The charge on the cloud may be so reduced in this way that the possibility of a huge flash to the earth through the building is greatly reduced.

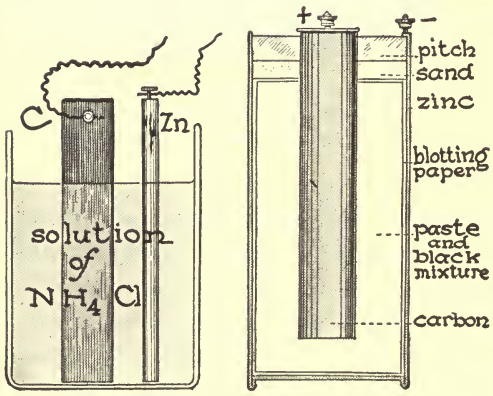


U. S. Forest Service

Lightning results from a discharge of electricity between two oppositely charged bodies. Do electrons play any part in lightning?

Current Electricity. If we rub wax rapidly with a dry piece of woolen cloth, we can electrify it. The wax is then said to be charged with electricity. A charged body such as this is one in which electricity is at rest. To be sure, the amount in the wax is very, very small, but if we were to connect two oppositely charged bodies, negative and positive, with a good conductor, such as a metal wire, electricity would flow for just an instant from one body to the other. Electricity in motion, as this is, is called *current electricity*, and this means nothing more than a flow of electrons. This is the kind of electricity which we use in ringing our doorbells, in running our motors, and in lighting our homes.

Electric Cells. You may have heard the terms "dry cell" and "wet cell," and doubtless some of you have seen them in your homes, as these two kinds of cells are used to ring electric doorbells. The wet cell is made by nearly filling a quart jar with a saturated solution of ammonium chloride. In this jar a large carbon plate and a zinc rod are suspended side by side, but not touching each other. When the ends or *poles* of these elements are joined with a wire electricity results through the release of chemical energy. The zinc rod and the ammonium chloride are gradually destroyed and must be replaced from time to time.



In both the wet cell and the dry cell it is the chemical action between the zinc and ammonium chloride that produces the electric current. Why is the dry cell used more than the wet cell?

In the dry cell, the zinc used is placed on the outside of the cell, making a container for the other materials, while the carbon is a large rod in the center. Between these are the chemicals, a paste of ammonium chloride being placed next the zinc and a layer of manganese dioxide around the carbon. The carbon pole is called the positive (+) pole, while the zinc is called the negative (−) pole. A current of electricity will flow through a wire which connects these poles. Dry cells have come to replace the wet cells in our homes to a large extent because they are more convenient to handle.

What Produces the Light in a Flashlight? When an electric cell has been used for a long time, it may fail to produce any more current. In the case of the wet cell, you will very likely find that one of the plates in it has been used up. This suggests that some vigorous chemical action has taken place in the cell between the solution and the plates. This is true. The cell is really a device by which energy resulting from this chemical action in the cell changed into electrical energy. This electrical energy can be changed to heat energy and light energy as it passes through the tiny bulb of the flashlight.

SELF-TESTING EXERCISE

Select from the following list those words which best fit the blank spaces in the sentences below and arrange them in proper numerical order. A word may be used more than once.

attract	neutral	ammonium	conduction
silver	brass	nickel	chemical
repel	negative	electrons	insulators
nucleus	silk	line	conductor
attracts	friction	gold	metal
repels	contact	protons	charge
positive	induction	wool	current
copper	electricity	sodium	cotton

Every (1)____ body contains equal amounts of (2)____ and (3)____ electricity. (4)____ between two unlike substances as

sealing wax and wool will produce two unlike charges of (5)____. The nucleus of every atom of matter contains positive particles called (6)____. Around this (7)____ revolve. When glass is rubbed with silk, (8)____ go from the glass to the silk, making the glass (9)____ because of the excess of (10)____ in it and the silk (11)____ because of the excess of (12)____ in it. Electrons (13)____ electrons and protons (14)____ protons, but protons (15)____ electrons. Current electricity is merely a flow of (16)____ along a (17)____. (18)____ are materials which do not allow electricity to pass readily. In electric cells, electricity results from an expenditure of (19)____ energy. The common dry cell has two plates, zinc and carbon, and the active chemical (20)____ chloride.

STORY TEST

Wendell Experiments at Home

Read carefully and critically. List all the errors and suggest corrections.

I know that friction produces heat, but I have been puzzled to know why it is only in cold weather that I can get enough heat by rubbing the fur on my cat's back to make sparks of fire. Last night I rubbed a comb with flannel and the comb received electrons from the flannel. I touched small bits of paper with the comb. They clung to it at first but soon jumped off. Since they were attracted at first I think they must have had a positive charge, and when they jumped off we know they were positive because they were repelled. A positive charge is easily produced by rubbing glass with silk. The protons go into the glass, making it positive. This morning I got a dry cell at the store. I connected it through a button with wire to an electric bell. In connecting to the battery I was careful to have the string or cloth covering of the wire kept in place when I screwed the nuts over the wire on the binding posts because if the bare wire touched them it would make a short circuit and ruin the battery. When I pressed the button the bell did not ring. This shows that the battery was old. I shall take it back to the store and exchange it for a fresh battery.

THE REVIEW SUMMARY

In this unit we have only begun to find out some of the facts about electricity, therefore you will not be able to give all the generalizations that you would give later on. See if you can add any to the ones that follow:

1. There are only a few metals that can be magnetized or that can be attracted by a magnet.
2. Electric charges can be given to bodies of matter. Non-conducting bodies hold these charges for a time.
3. Electricity is believed to consist of negative particles called electrons and positive particles called protons.
4. Electrical energy is produced only at the expense of some other kind of energy.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of the statements you believe to be incorrect. Your grade = right answers* $\times$ 5.

I. **When glass is rubbed with silk:** (1) the silk takes a negative charge and the glass a positive charge; (2) the glass is electrified but not the silk; (3) the amount of electricity produced is the same in both bodies; (4) the glass and silk will repel each other.

II. **Electricity may be produced by:** (5) friction between paper and cloth; (6) putting rods of aluminum and iron into a salt solution and letting the outside ends touch each other; (7) chemical action in a storage battery; (8) an electric motor.

III. **Every magnet has:** (9) two poles which attract iron; (10) two unlike poles; (11) a magnetic field; (12) an electric current surrounding it.

IV. **A dry cell:** (13) produces electricity from chemical energy; (14) contains no water; (15) has two poles, north and south; (16) produces no current on a closed circuit.

V. **The needle of a magnetic compass:** (17) is a temporary magnet; (18) points to the earth's geographic north pole; (19) takes the direction of the earth's lines of magnetic force; (20) always points in an east to west direction.

THOUGHT QUESTIONS

1. What are some objections to the use of the magnetic compass to direct the course of a ship?

2. How can you take electrons away from a glass rod? How can you add electrons to an insulated piece of metal?

3. Why does a person become charged with electricity when scuffing over a carpet on a day when the air is dry?

4. Why is a spark sometimes produced when one rubs the cat's fur backwards?

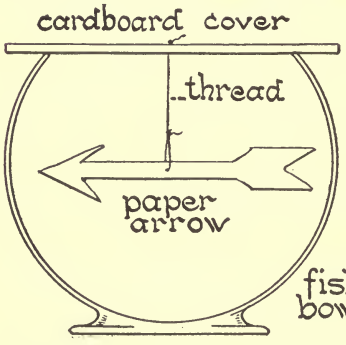
REPORTS ON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. The story of Galvani and Volta.
3. What Benjamin Franklin did for electricity.
4. The use of lightning rods.
5. The passing of the magnetic compass on ships.

SCIENCE RECREATION

1. The Obedient Arrow

Procure a dry fish globe. Cut a cover for it from cardboard. Cut an arrow from stiff letter paper. Suspend the arrow, carefully balanced, in the middle of the globe by a very fine thread. Fasten to the center of the cardboard cover. Tell the arrow to turn to the point on the jar which you rub. Rub the outside of the glass up and down at a place about two inches to the right or left of the place where the arrow points, then rub another place a few inches away. Rub your hand over the place electrified if you wish to take the electricity away and let the arrow go back to its original position.



2. A Balloon Welcome

Blow up a rubber balloon until it is about eight inches to ten inches in diameter. Tie tightly. Suspend by a string about three feet from the wall and nearly in the path of a person who comes through the door into the room. It should be shoulder high. On a day when the air is very dry (a cold winter day is best)

rub it briskly all over with a piece of fur or wool. Call some people into the room and if they pass close to the balloon, they will be surprised at the result.

3. Make an Electroscope

Fasten a piece of silk thread to a celluloid ping-pong ball or to small pieces of cork. Hang this eight inches below a support. Use this to see if objects like sealing wax, fountain pens, and combs when rubbed with fur, wool, or silk are electrified.

4. A Taste of Electricity

Get a strip of copper and a strip of zinc about $\frac{1}{2}$ inch wide and two or three inches long. Fasten a copper wire to one end of each. Touch the tongue with the two free ends of the copper wires. Hold the ends of the wires not more than $\frac{1}{2}$ inch apart. Dip the ends of the metal strips (must not touch each other) into a salt solution. Take off the copper wire, and bring the ends of the two strips to the tongue quite near each other. Can you detect a difference in taste when the current flows and when it does not?

5. Electricity from a Lemon

Use the zinc and copper strips in Demonstration 4. Cut two slits in a lemon $\frac{1}{2}$ inch apart. Work the knife around in each to cut the tissue. Push the two strips of copper and zinc into the slits but do not let them touch each other either inside or outside the lemon. Test by taste to see if an electric current is produced. Test with a compass.

SCIENCE CLUB ACTIVITIES

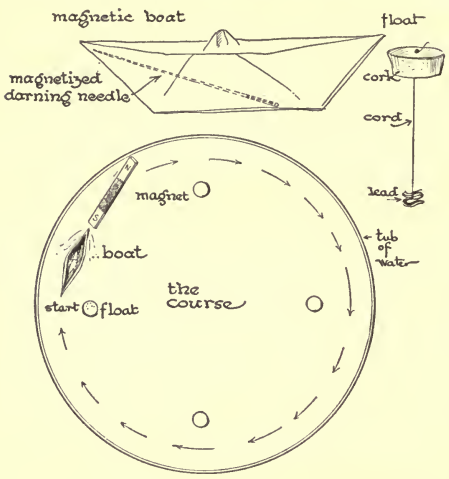
1. Electrostatic Race

Make your preliminary tests at home. What can you find that will give you the strongest electric charge — wax, comb, fountain pen, rod of ebonite, hard rubber, or glass? Which gives you the best results — wool, fur, or silk? When satisfied with your results, enter your science club contest which will be held on a named future date. Pieces of paper of graded sizes will be provided, and the contest is to see whose equipment, which he brings from home, can lift the largest piece of paper clear from the table.

2. A Magnetic Boat

Build your boat upon any design you may devise. The following suggestions may be useful to you: For the magnet use a

darning needle, or a piece of watch spring about 3 inches long. Make a paper boat about 4 inches long. Paraffin the outside and seams if made from pieces rather than folded. After magnetizing the steel, lay it in the boat and cover with a thin layer of melted paraffin. Two such magnets may be used if desired. On the club race day have a tub of water. Anchor 3 or 4 cork floats to mark off the course. Boats must go around the course outside these floats. The same magnet is to be used by each contestant. This should have a wire extension so that the magnet can never be brought nearer than 6 inches to the boat. A stop watch is needed to time each boat, because each boat must be taken around the course by itself. The winner will be the one that makes it in the shortest time.

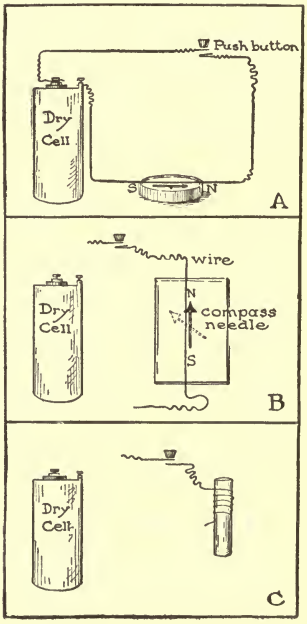


3. How to Produce a Magnet Using Electricity

(A) Connect a cell and push button as shown in diagram. Bring a portion of the wire down over and parallel to the compass needle. Press the button to cause an electric current to flow through the wire. Result?

(B) Diagram B represents a wire brought down over and parallel to the compass needle. Complete the wiring connections so that when the current flows it will make the north pole of the needle turn towards the west, as is represented by the dotted arrow.

(C) Wind an insulated copper wire in close layers around a soft iron rod, remove the rod, connect the ends of the



coil into the electric circuit. Hold one end of the coil near the north pole of the compass needle. Press the button to pass an electric current. Result? Hold the other end of the coil near the north end of the compass. Result? Make a similar test with the iron core inside the coil. Compare strength of magnetism. Complete diagram C. Label poles of the electromagnet correctly.

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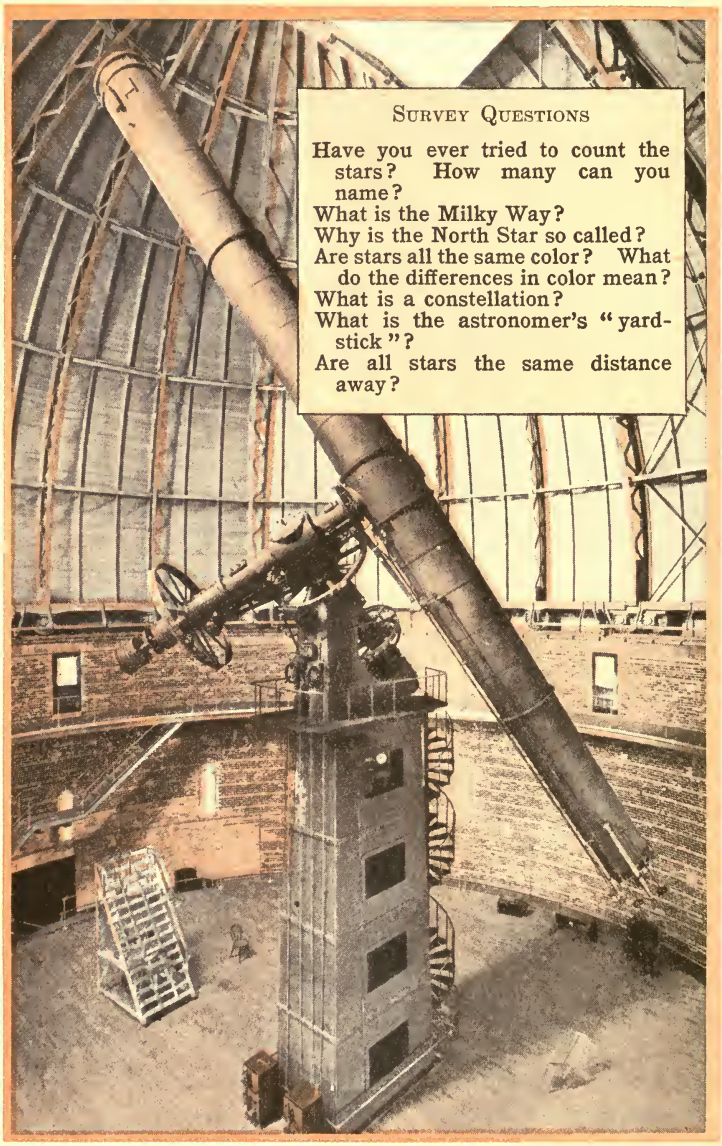


Survey Questions

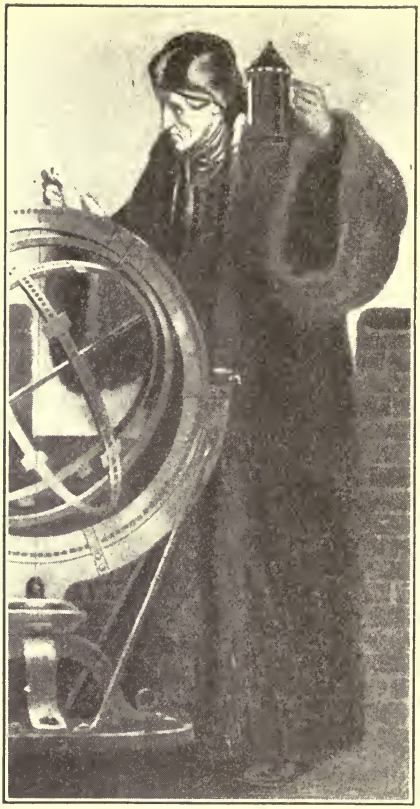
Have you ever tried to count the stars? How many can you name?
What is the Milky Way?
Why is the North Star so called?
Are stars all the same color? What do the differences in color mean?
What is a constellation?
What is the astronomer's "yard-stick"?
Are all stars the same distance away?

UNIT VIII

GETTING ACQUAINTED WITH THE STARS

PREVIEW

We have looked into the sky on a dark clear night and have seen multitudes of twinkling stars, some large and some small. If we look closely, we notice that some of the stars are of a different color, some bright red, deep blue, or white. Boys and girls who are scouts can pick out the North Star and some of the easier constellations. Doubtless boys and girls during the past ages have done the same thing. They have wondered about the stars and how far away they were. The ancients thought the sky was an inverted bowl and that the stars were holes through which light shone. Primitive man worshiped light because he was so much dependent on it. Ancient people studied the stars and used them as guides to help find their way about at night. It is little wonder that the ancients with so much leisure time should find the heavens interesting. Shepherds who watched the flocks by day also watched the stars by night. It is not strange that these imaginative and superstitious people of the olden times saw figures of people and animals in the stars, and created stories about their origin in the sky. Nor is it strange that they made a universe with the earth as a center, and believed that the stars in the heavens revolved around it. They knew that the sun and the moon and the stars helped them to keep time, and they also came, in time, to be more familiar with some stars than with



NICHOLAS COPERNICUS, 1473–1543.

COPERNICUS, as a Polish boy, studied Latin, Greek, and mathematics. It was believed at that time by every one that the earth was an immovable body suspended in space, and that the sun, planets, and stars moved around it. The lad studied medicine but was so interested in mathematics and astronomy that when an opportunity arose he became a professor. Later he became a canon, or priest, at the Cathedral of Frauenburg, in Germany. Here he had much leisure and devoted himself to the study of astronomy. Although he had no telescope, he cut slits in the walls of his home and timed the movements of the planets in that way. He came to the conclusion that the sun was the center of our solar system and that the earth and other planets revolved around it. This was a theory then, but we know it to be a fact today.

others. Some of the better informed men became astrologers. These men believed that the stars exercised magic influence over people, and that such people must do the things that the stars ordered them to do. Even today we see ignorant people believing in the predictions of fortune tellers who say that they live under a lucky or an unlucky star. Some of our superstitions of today have been handed down from very ancient times.

But the early astrologers knew a great deal about some of the stars. They could tell several planets and gave them names. The name "planet" itself comes from the Greek word meaning to wander, for they saw that these heavenly bodies moved about. The old astronomers could predict with a good deal of accuracy the movement of some stars, although they did not know what caused them to be seen in different positions in the sky. The old idea was that the earth was fixed, and it was not until the 16th century that Copernicus,[1] a Polish clergyman, proved that a number of planets were revolving in space around the sun. He believed our own earth was one of these and that the earth rotated on its axis, making it appear as if the stars moved about the earth. In the units that follow, we shall build on the experiences we have had in our geography and try to get a little more knowledge about some of our neighbors in space.

PROBLEM I. HOW FAR AWAY ARE THE STARS?

When we look up into the sky, we may think that we see myriads of stars, but if we try to count them, we are surprised to find that we rarely see more than 2000 or 3000 at one time. If we were to look through a big telescope, such as they have at the Mount Wilson Observatory in California, we could see thousands of stars where we saw only one with the naked eye. This is so because the

[1] Copernicus (kō-pûr'ni-kŭs).

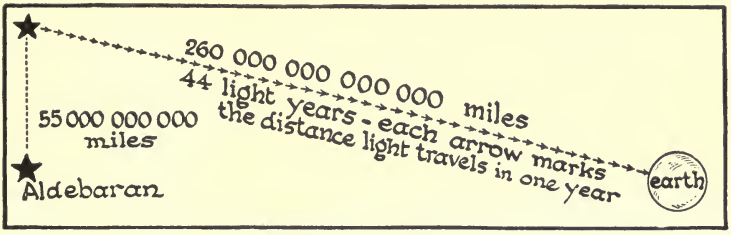
telescope shows us bodies whose light is too dim to be seen with the unaided eye. But if we were to expose a photographic plate behind a telescope lens for several hours under the same space in the sky, we would be amazed to find when the plate is developed that not thousands but hundreds of thousands of stars will appear where we saw only a few with our naked eye. The reason for this is that the chemicals on the plate are sensitive to rays of light too weak to register in the human eye, even when we look through the telescope.

The Astronomer's Yardstick. When we look up at the stars, we realize that some are much larger and some much brighter than others, but all look to be very far away. As a matter of fact, some are very much farther away than others. Some appear nearer because they are more brilliant. Astronomers tell us that the nearest fixed star [1] is over 25,000,000,000,000 miles away. Light travels a little over 186,000 miles a second. In a year

Soibelman Syndicate

This shows a portion of the sky as seen through a large telescope. How many of these stars do you think you could see with the naked eye?

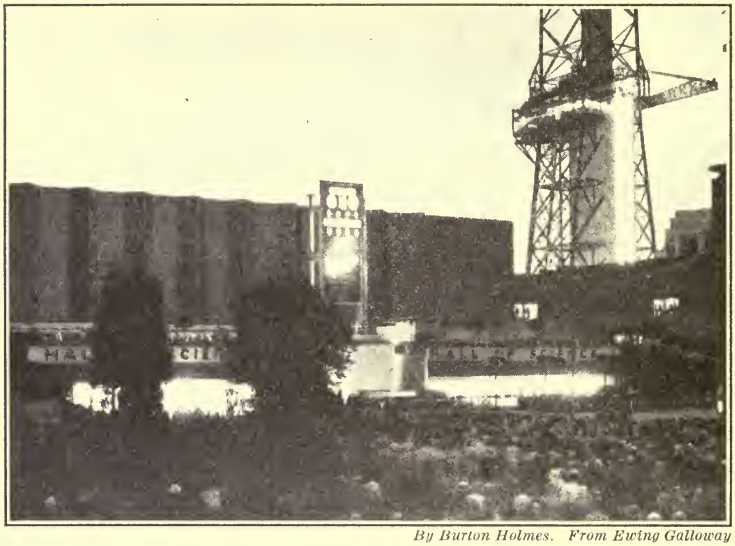
[1] Proxima Centauri.



The light by which we see Aldebaran today left that star 44 years ago, and we apparently see it as the upper star. But in that time the star has moved many miles and it is really at a point 55 billion miles away from the place where we appear to see it.

it travels about 6,000,000,000,000 miles, so that it takes a little over 4 years for light from the nearest star to reach us. The distance light travels in one year is called a light year. This is the astronomer's yardstick or a way of measuring distances. When the astronomer tells us that there are probably many hundred thousands of light years separating us from some of the more distant stars, we can see that the distance of the stars from the earth varies greatly.

Distances to the Stars Are Enormous. There have been many comparisons devised to make the enormous distances to the stars understood. None of them help very much, but that of Dr. Brashear, at one time a famous lens maker of Pittsburgh, is at least interesting. In the eyepiece of many telescopes a "cross hair" is used. This had to be finer than any thread. Even the fiber of the ordinary spider web is too coarse, but the mother spider spins a very fine and delicate fiber to make the cocoon which protects the young. These fibers were used by Dr. Brashear in his telescope, and he became interested in calculating how far so thin a fiber could reach. A pound of it would circle the earth at the equator and ten pounds would make enough fiber to reach the moon. How much of this fine fiber would be required to go to the nearest star $4\frac{1}{3}$ light years away? By Dr. Brashear's calculation



By Burton Holmes. From Ewing Galloway

Here, in the Court of Honor in front of the science building, light from Arcturus, which had left the star forty years ago, set off the lights of the Century of Progress. The illuminated board which secured the starlight from one of the co-operating observatories is seen in the center of the picture.

it would require 500,000 tons to reach the nearest star, and to reach the North Star, it would take over 55,000,000 tons.

How Starlight Opened the Century of Progress Exposition. In 1933 the World's Fair in Chicago was opened officially by an electric current set up by light from the star Arcturus. The light from this star, which reached the earth in 1933, left Arcturus 40 years earlier, or about the same time that the previous World's Fair had been held in Chicago. It is interesting to know how this starlight was used. Light from the star was collected by a large telescope and focused on the interior of a photoelectric cell. Photoelectric cells are capable of transforming light energy into electrical energy, and this cell transformed the light from Arcturus into a current of electricity which was amplified and sent by wire from

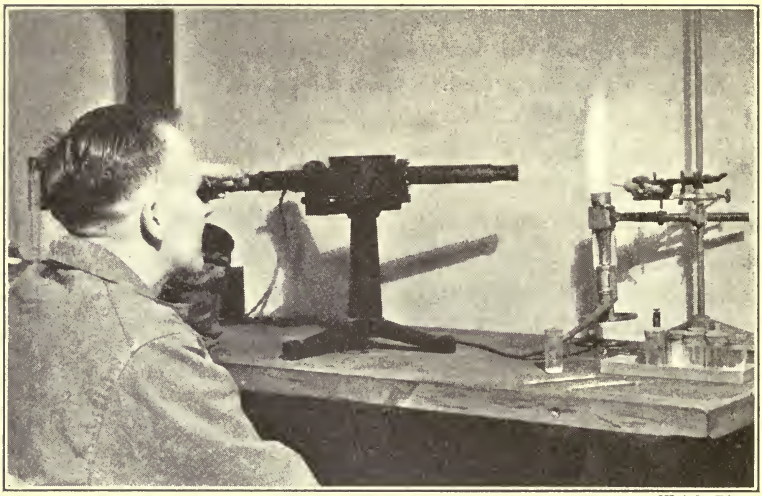
the observatory to Chicago. Here it operated machinery which turned on the lights and opened the Fair. Each night the great batteries of electric lights at the Century of Progress Exposition were turned on by means of the light from this same star sent from one or more of the observatories which co-operated in this interesting service. If the distance to Arcturus were expressed in miles, it would be about forty times six million million. Can you express this in figures?

Star Magnitudes. Any one who has seen the heavens on a clear night knows that the brightness of the stars varies greatly. The faintest star visible to the unaided eye is called a sixth magnitude star. This furnishes the basis of classifying them. The table which follows gives a rough comparison of magnitudes or brightness.

Magnitude	Times Brightness of Sixth Magnitude Stars	Approximate Number of Stars of This Magnitude in the Whole Heavens
6	1	5000
5	$2\frac{1}{2}$	1500
4	6	500
3	16	200
2	40	60
1	100	20

The apparent brightness of a star depends upon its temperature, size, and distance. Other things being equal, the nearer the star to us, the brighter it seems. The North Star is about as bright as Betelgeuse, but it appears much dimmer because it is more than twice as far away from us, and yet it appears brighter than some nearer stars which are smaller and cooler.

What the Color of Stars Tells Us. The unaided eye can easily notice a difference in color of some of the stars. When an iron rod is heated in the furnace, the first



Wright Pierce

This picture shows how the spectroscope is used. By means of this instrument the materials burned in the flame at the right are known by the patterns or bands they make in the spectrum of the instrument.

indication of its becoming luminous is shown by a dull red color, which, as it is heated longer, may change to orange or yellow. If it is placed in a very hot furnace, it finally becomes "white hot" and gives a brilliant whitish light. Evidently, then, the color of a luminous body differs with its temperature. This experiment gives us some evidence on the temperature of stars. Our sun is believed to have a surface temperature of about 11,000° F., and gives a yellowish light. Some stars have exactly the same color as the sun, and when seen through an instrument called the spectroscope, they have the same spectrum as the sun and so are believed to have about the same temperature as the sun. Betelgeuse is a red star and hence is not as hot as our sun, while Sirius, the Dog Star, shines with a bluish-white light which indicates that it is hotter than the sun. Half of the stars are white, while most of the others are yellow. Some bodies that were

stars once now have so little light and heat that they do not even glow. They have become cold bodies like our earth and our moon. The color band and its position as seen in the spectroscope help astronomers to tell whether the star is moving away from us or coming toward us.

SELF-TESTING EXERCISE

Select from the following list the words that best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

million	years	red	color
tenth	month	black	photography
first	century	white	periscope
thousand	Heavens	light	telescope
100	orange	dark	sixth
year	yellow	stars	fourth

More stars in the (1)____ are discerned by (2)____ than can be seen through a (3)____. (4)____ travels faster than any other known thing. In astronomy the unit of measure for distance is the (5)____ (6)____, which equals six (7)____ (8)____ miles. The nearest star is about $4\frac{1}{3}$ (9)____ (10)____ away. The faintest star we can see is a (11)____ magnitude star. A first magnitude star is (12)____ times as bright as this. The age of a star is told by its (13)____. Young stars are (14)____, while old stars are (15)____ or (16)____.

STORY TEST

Ursula Visits a Great Observatory

Read carefully and critically. List all the errors and suggest corrections.

I recently enjoyed a rare privilege. It was open night at the Harvard Astronomical Observatory. Through a 10 in. telescope I saw the red Rigel and red Mars. Rigel is ever and ever so much hotter than our sun and the other stars. As I looked at it I could feel the intense heat coming through the telescope, and no wonder, because it is 25,000 times as hot as the sun. I asked if I might see the astronomer's "yard stick" with which they measured the distance to the stars. I wonder why they laughed, but anyway they said that they never let the public see it. On one of the roofs without any telescope we were shown constellations

made up of stars of varying brightness. We could see stars varying from the 1st to the 10th magnitude. I must have counted at least 30 first magnitude stars, the brightest of them all was Betelgeuse.

PROBLEM II. WHY DO THE STARS APPEAR TO MOVE?

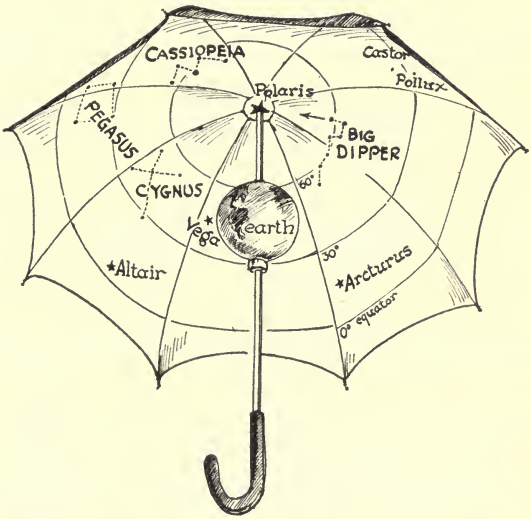
The Earth Is Moving through Space. We must go back to our geography to answer this question. The earth is a nearly spherical body which rotates on its axis once in every 24 hours. We also know that it revolves around the sun once every year. If we think of the size of the earth and remember that it is about 25,000 miles in circumference at the equator, we may imagine a city there whirling around the earth's center at a rate many times as fast as the fastest mail plane can travel. If we bear in mind the rotation of the earth on its axis, we can understand

The fact that the earth is revolving is shown in this photograph. The fixed stars make trails on the plate. Can you locate the position of the polar star? In what hemisphere must this photograph have been taken?

why it is that the sun, moon, and stars appear to rise and set. The earth also rushes through space around the sun at a rate of about 1100 miles a minute. If we also remember that we are moving rapidly through space, we can see why constellations do not always appear to be in the same place in the heavens. Those of us who are scouts know that certain groups of stars called constellations are visible in the winter and that six months later others have come above the horizon and occupy the places held by those we saw in the winter. The reason for this is evident when we recollect that in the summer our earth is in quite a different place in space than it is in winter. We have moved along to the other side of the sun in a circular path whose diameter is 186,000,000 miles.

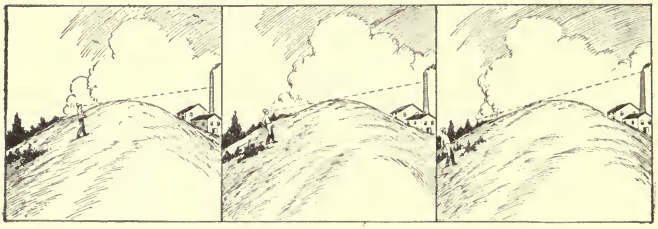
Demonstration 1. How the Rotation of the Earth Causes Stars to Appear to Move.

Hang a large round umbrella in the room so that the supporting rod is in direct line pointing to the North Star. A compass will show you north. There are 90° from the equator to the north



pole. Paste a paper star around the umbrella rod where it passes through the cover of the umbrella. As you look up into the umbrella, you see this star where the North Star would be. Place other paper stars in positions to represent the Big Dipper and one or two other constellations. Make holes at the poles of a small globe, place it on the umbrella rod so that it will rotate under the umbrella. The North Star is now directly in line with the axis of the earth represented by the rod of the umbrella. In place of a globe, a ball, an apple, or an orange may be used. The latitude of the place where you live equals the number of degrees it is north of the equator. Mark the spot on the globe where you live. Now imagine you are on the earth. Hold the umbrella still. Rotate the globe and observe the direction in which you would look to see the North Star at different times. Observe the direction in which you see the end star in the Big Dipper. Rotate the globe from west to east far enough to represent six hours' time, or one-fourth of a revolution. Now observe the direction in which you would look to see the same star. In what direction would the star appear to have moved?

Why Do Stars Rise and Set? Suppose we are standing at a certain place on the surface of the earth as it rotates on its axis. After a complete revolution on its axis during a period of 24 hours, we are brought back to the same place. This turning as we look at the stars gives them the appearance of rising and setting. If you walk up a



Explain by means of this diagram why stars appear to rise and set.

long hill behind which is a factory with a tall chimney, the higher up the slope you go, the more you see of the chimney. It appears to rise. If you go backwards down the hill, you see the chimney gradually disappearing be-

hind the hill. We may think of it as setting. When the moon comes up or sets, it just means that we have traveled past it as we dash by objects on a railroad train. It is in the same way that we move past stars of the constellations. Stars seem to move across the sky from east to west, but the earth is really rotating from west to east. Consequently they appear to rise and set. There is one star, however, that does not appear to move. This is Polaris, the North Star. The reason for this is that it is in line with the axis of the earth, as is shown in the demonstration we just performed. Now, because the earth rotates, the stars appear to describe circles around the earth. If the earth is held still while the umbrella is rotated east to west, and you imagine yourself at a fixed spot on the earth, you will readily see the apparent motion of the stars.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

always	north	move	spherical
never	south	motion	earth
hallucination	east	movement	star
illusion	west	rotates	equator
near	sun	speeds	axis
distant	moon	revolves	poles
			latitude

The earth in form is a (1)____ body. It (2)____ on its (3)____ and (4)____ around the (5)____. The axis of the earth points towards the (6)____ (7)____ which (8)____ appears to move. All the other stars appear to (9)____ from (10)____ to (11)____ during the night. But this (12)____ is really due to the (13)____ of the (14)____. The fact that we do not see the same stars at different seasons is explained by the (15)____ of the earth to (16)____ parts of the heavens as it revolves around the sun.

STORY TEST

SYBIL HAS A UNIQUE WAY OF EXPLAINING WHY THE STARS APPEAR TO MOVE

Read carefully and critically. List all the errors and suggest corrections.

I play that I am the earth and my eye is a person on the earth. I stand near one end of the room. I name different objects in the room "stars." Directly over my head is the North Star. Unfortunately my eye does not extend out from the surface of my face as people stand out above the surface of the earth, and so my eye cannot see the North Star. I play it is sunset in September. I rotate slowly. When halfway around it is sunrise and the night is over. The objects representing stars passed before my sight just as if they had been moving and I had been still. I then move to the opposite end of the room. It is now sunrise in March. I rotate halfway to represent the night. I see some of the stars (objects) that I saw before and some different ones. But the positions in which I see them appear quite different. After this experiment it is quite easy to understand how the two movements of the earth can produce the common illusions of the movements of the stars.

PROBLEM III. HOW TO GET ACQUAINTED WITH THE CONSTELLATIONS

If you live in the northern hemisphere and look towards the north on any clear night, you will find the Big Dipper. The two stars on the side of the dipper away from the handle are called "the pointers." If you use these for direction and follow this line from the bottom of the dipper into space, you will presently come to a star not quite so bright as those forming the bowl of the dipper. This is Polaris, the polar or North Star. It is the star that has guided travelers since ancient times. When we see it, we should remember that the light which enters our eyes is believed to have left that star more than 450 years ago. The light by which you see the North Star left it before Columbus, guided by that same star, discovered America. That starlight has been traveling at the rate of 6,000,000,000,000 miles a year all these long years. Since the North

Star is practically in line with the axis of the earth and all other stars keep the same relative position to the North Star, there is apparent rotation of all the other stars about Polaris in the center.

Star map of the region about the North Star (pole star). If you face north at 8 P.M. and hold this map in front of you with the name of the present month at the bottom, you will find these five constellations in the relative positions indicated on the map.

How the Stars Got Their Names. Many boy and girl scouts may have studied the stars enough to know the names of some of the constellations. Ancient peoples in their study of the heavens saw many wonderful creatures there, dragons, horses, lions, dogs, as well as many mythological characters. These groups of stars have been called constellations. There are 48 constellations named by ancients and about 40 more have been added in later times. Some are called by very ordinary names such as the Big Dipper and the Little Dipper, which you have all seen. But these same constellations have also been given other names, the Great Bear and the Little Bear. Many of the star groups have Greek or Roman names which have come down from the ancient times because of the stories that the ancient peoples told about these figures in the sky. It is interesting to know that certain constellations known to the Egyptians, Chinese, the Greeks, and our American Indians had the same names given them by these different peoples. For

example, the constellation we call the Great Bear was so named by the Chaldeans, Greeks, and American Indians:

Is this a modern or an ancient map of a portion of the heavens? Give the reason for your answer.

groups of people who had no connection with each other at any time during their existence.

The Big Dipper. One of the most conspicuous star groups or constellations is the Big Dipper. From it you can find the North Star and then work out to other groups. Polaris, also a second-magnitude star, is at the end of the handle of the Little Dipper. The two second-magnitude stars in the end of the bowl away from the handle are

called "pointers." They point to the polar star, Polaris. The position of these and other constellations differs with the season. As the earth moves along its orbit to new positions in the heavens, the stars overhead at 8 P.M. will vary greatly at different times of the year. If you observe the Big Dipper in early evening as soon as visible, and again the same evening three or four hours later, you can see that its position in the heavens changes.

How to Tell Some of the Constellations. We can easily find a number of the constellations if we know the position of the Big Dipper and the Little Dipper. A study of any good star map will show you that if you follow the pointer of the Big Dipper to the North Star and then continue about an equal distance beyond, you will see a little to the right a constellation whose bright stars roughly form the letter W. This is the constellation Cassiopeia. If you go from the pointer to Polaris and turn at right angles and travel nearly twice the distance, you will come to a very bright red star, called Capella. From the pointer at the open end of the bowl draw a straight line to the handle side of the bowl one-third of the distance down from the rim of the bowl and continue in the same direction to a bright star which is twice as far from the North Star as the bowl of the Dipper is. This is Arcturus in the constellation Boötes. Arcturus is a first-magnitude star 500 times as large as our sun and gives a white light. We have already seen that it takes about 40 years for its light to reach the earth.

By studying the star maps shown on pages 204 and 205, you can locate a number of the more common constellations such as Orion, with its three-starred belt, and the bright stars Rigel and Betelgeuse; the Twins; the Great Dog Star, Sirius, which is the brightest star in the sky; and many others. Remember that the maps made for use here show you the situation in the sky during the

JANUARY

APRIL

FEBRUARY

MAY

MARCH

JUNE

JULY

OCTOBER

AUGUST

NOVEMBER

SEPTEMBER

DECEMBER

months of November, January, March, and June in the northern hemisphere, and that if you see the same heavens six months from these dates, the constellations will have quite a different position in the the sky, as can be seen by comparing the maps on pages 204 and 205.

What Is the Milky Way? If you look up into the sky on a clear moonless night, you will see an irregular belt-like luminous cloud extending clear across the sky which varies in brightness in different places. It seems like a pathway in the heavens, and for this reason has been called the Milky Way. This is best seen in September. In ancient times the Milky Way was thought of as a pathway to heaven over which those who died had to travel. It has also been called by such names as Jacob's Ladder and the Pathway of the Souls. Of late years our powerful telescopes have revealed much more about the true nature of the Milky Way. It is made up of millions of stars, masses of incandescent matter, and perhaps bodies like our planets, moons, and material out of which comets are made. All the stars that we see through telescopes are luminous bodies like our own sun. This great system of stars that we see in the Milky Way is called a galaxy, and since our own sun is a member of this galaxy, we belong to it also. Many other galaxies have been discovered in the very distant heavens, of which we will learn something later.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

earth	north	Big	first	handle	cloud
northwest	south	Little	second	bowl	Polaris
sun	east	medium	third	dipper	Cassiopeia
stars	west	Great	thousands	trillions	pointers
planets	up	Small	millions	northeast	constellation
galaxy	down	magnitude	billions	fourth	luminous

The two second (1)____ stars on the side of the (2)____ (3)____ opposite the handle are called the (4)____. They show the direction to (5)____. Almost opposite the Big Dipper on the other side of the North Star is the (6)____ called (7)____. Polaris is the star at the end of the (8)____ of the (9)____ (10)____. If the handle to the Big Dipper points southeast at 6 P.M., it will point (11)____ at 9 P.M. and (12)____ at 12 midnight. Polaris is a (13)____ magnitude star and Sirius and Arcturus are (14)____ magnitude stars. The Milky Way seems like a (15)____ (16)____ but in reality is chiefly a cluster composed of (17)____ of (18)____ and is called a (19)____ of which our own (20)____ is a member.

STORY TEST

EVELYN LIKES TO STUDY THE STARS. HAS SHE PROFITED BY HER STUDY?

Read carefully and critically. List all the errors and suggest corrections.

The heavens are just full of stars grouped together in consternations. The largest of these is the Milky Way. Last night I saw Orion. I recognized it by the 3-star belt and the 2 bright stars, Altair and Arcturus. I also saw Procyon in the Little Bear, and the brightest of all stars, Sirius, in the Great Bear. In the early evening the pointers in the Big Dipper pointed northwest and towards Polaris, but six hours later they pointed northeast and away from Polaris. Cassiopeia appears to travel a complete circle around the North Star every 12 hours, but stars farther from the polar star like Sirius require 24 hours to make the circuit because of the greater distance the star has to travel. If we stood over the north pole in winter, Polaris would be directly overhead, but in summer it would be $23\frac{1}{2}$ degrees farther south.

THE REVIEW SUMMARY

We might study astronomy all our life and still know very little about the stars. However, scientists have agreed that there are a few general facts or generalizations that almost any one can learn about these wonderful neighbors of ours in space. These generalizations are:

1. There are many more stars than we can see.
2. The stars are so far away it takes light from them many years to reach us.
3. The rotation of the earth on its axis causes an apparent daily rotation of the stars.
4. Stars vary greatly in size, brightness, and distance.
5. All the stars we ever see with the unaided eye make up a small part of a huge group called a galaxy.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of the statements you believe to be incorrect. Your grade = right answer* $\times 2\frac{1}{2}$.

I. **The process which discloses the largest number of stars is:** (1) counting them on a very clear night; (2) looking through a powerful telescope; (3) by photography; (4) by using an enlarging camera.

II. **By the magnitude of a star is meant:** (5) its distance away; (6) its size; (7) its apparent brightness; (8) its real brightness compared to the sun.

III. **When a star gives a white or bluish white color, it is evidence that the star is:** (9) very hot; (10) very near; (11) a young star; (12) hot, but not so hot as our sun.

IV. **The stars in the sky:** (13) keep their positions almost unchanged year after year; (14) really move across the sky daily; (15) would not appear to move if the earth were still; (16) constantly change their relative positions as do the drops of water in the ocean.

V. **The Big Dipper:** (17) is a galaxy; (18) contains "the pointers" for locating Polaris; (19) revolves around the sun; (20) appears to revolve around the North Star every 24 hours.

VI. **There are stars so far away that:** (21) their discovery awaits the building of more powerful telescopes; (22) the light leaving them today will not reach the earth for a hundred thousand

years; (23) follow different physical laws from those of our own system; (24) they must be cold bodies.

VII. **When we look into the sky at 8 P.M. in December, we do not see the same constellations that we do at 8 P.M. in June because:** (25) it is colder weather; (26) the nights are longer; (27) the earth has moved halfway around the sun, changing the heavens which we see at night; (28) the stars have rotated halfway around the North Star.

VIII. **The North Star is:** (29) about vertically over the north pole of the earth; (30) visible to all people on the earth, because of its great distance above the earth; (31) more than two million billion miles from the earth; (32) also called the Little Bear.

IX. **The light year is:** (33) the time it takes light to come to earth from the sun; (34) the unit of measuring distances of heavenly bodies; (35) the distance light travels in a year; (36) about six million million miles.

X. **The Milky Way is:** (37) a constellation; (38) a galaxy; (39) a solid heavenly body; (40) is seen by reflected light just as the moon is.

THOUGHT QUESTIONS

1. Why do stars appear to move in a certain direction during the night?
2. Why do certain stars appear to change their positions from month to month?
3. Calculate how long it will take the light from a star selected by yourself to reach the earth?
4. Compare an atom of matter and our own solar system. Show how you will use facts, theories, and imagination in making this comparison.
5. How would you say that future discoveries in astronomy will be made?
6. How can we tell the age of a given star?
7. We say that the axis of the earth points very nearly towards the North Star. Can you explain how, in reality, this statement is very far from the actual fact?

REPORTS ON OUTSIDE THINGS THAT I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.

2. The value of Galileo's telescope.
3. Ideas of ancient peoples about the heavens.
4. Kinds of telescopes.
5. Famous observatories.

SCIENCE RECREATION

1. What Progress Has Science Made on the Earth Since the Beam of Light by Which You May See Arcturus Left It?

Ask your grandparents about the wonders of science 40 years ago. Write up the story of scientific progress that has been made on the earth during the time that beam of light traveled through space.

2. Make a Luminous Star Chart.

Fit a box approximately four inches on a side over the end of a hand flash lamp. The side of the box opposite the lamp bulb is open to hold the star charts. These are cut out of black paper a trifle larger than the opening in the box. The center of the box cover is cut out nearly to the edge. When this is put on the box over the star chart, it will hold it securely in place. Consult a good star map. Mark on the black paper the relative positions of the principal stars in a constellation. Prick holes through. When in place on the box, the light shines through and shows you just what to look for in the sky. Make as many constellation charts on separate sheets of paper as you desire to locate. The following constellations are suggested as interesting groups to locate: The two dippers, Cassiopeia, Orion, the Northern Cross, Pegasus, Sickle, Lyra, and the Pleiades (Seven Sisters).

SCIENCE CLUB ACTIVITIES

1. Making Star Trails

Have the club meet in the evening. If in the city, get permission to use the roof of some tall building, but it is better to go out into the country where no artificial lights will cast a haze, and so dim the light of the stars. Have at least two cameras loaded with very fast film, such as supersensitive phenachrome. Open the diaphragms wide, and set the lever for time exposures. Point one camera directly at Polaris and the other at the brightest star nearly overhead. Fix the cameras so that they cannot move. Open the shutters and allow them to stay open one and one-half to two hours. You can go away and have an indoor meeting and

make a luminous star chart, or study the star groups with your chart, if you have one already made. When your film has been developed and printed, you will find curved paths circling part way around the polar star but nearly straight paths in the picture taken overhead. You should be able to explain why these trails are not alike.

2. What Is Your Speed and Where Are You Going?

In addition to considering and making the calculations suggested here, ask members to look up and report to the club any information — facts or theories — that has to do with our movements in space.

a. If you were at the equator, how far would the rotation of the earth on its axis carry you in twenty-four hours?

b. If you were right over the North Pole of the earth, how far would the rotation of the earth carry you in twenty-four hours?

c. If you live about halfway from the North Pole to the equator, how far will you travel in twenty-four hours?

d. If you are moving at the rate of eighteen and one-half miles per second, along the orbit of the earth around the sun, how many miles do you travel in a day of twenty-four hours?

3. Make a star map for the present month.

4. Make a simple telescope.

5. Report on the beginnings of astronomy.

6. Report on a modern astronomical observatory.

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Survey Questions

If the earth was once all molten rock, how can you account for the soil and water now formed on its surface?

Did you ever find a fossil? How do you think it was made?

What are some evidences of the force of water?

How are the active forces of nature of vital importance to a farmer?

Do you know what kinds of soil hold water? What kinds are porous? What kinds make the best soil for growing crops?

Why are fertilizers added to soil?

Photo by E. S. Shipp. Courtesy U. S. Forest Service

UNIT IX

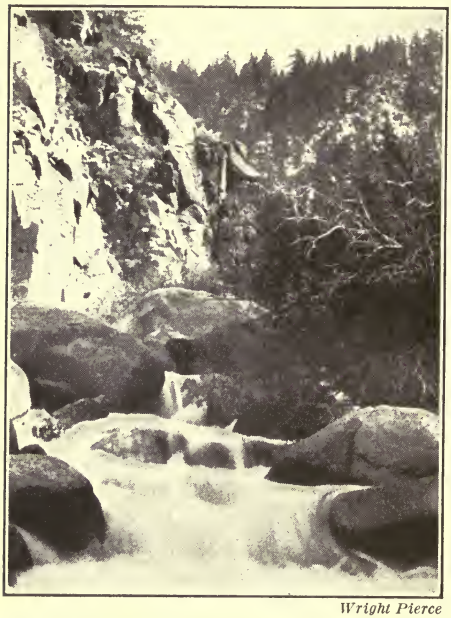
ROCKS AND SOIL

PREVIEW

How many of you have ever been to the top of a high mountain? You remember how it looked — a great mass of solid rock with perhaps a few trees clinging here and there in places where there was a little soil. If you worked your way down the mountainside, you would probably follow the course of a tiny brook which, as you descended, you would notice had cut its way deeper and deeper between rocky walls and slopes of broken particles of rock. Look at those rocks carefully. They all seem to be angular bits, not rounded like the pebbles you find in the valley at the foot of the mountain or on the beach. The rocks on the mountainside look as though they might have been cracked off and broken up by some force, perhaps great heat or cold. Let us scramble down a little lower. Trees, shrubs, and plants begin to be more numerous, the rocks are giving place to soil, some of it black and rich. You find more inhabitants of the forest — birds, squirrels, and other small animals. If you dig in the ground, you may find earthworms, beetle larvae, and other living things. The brook is inhabited, too: insect larvae in the water, flies and mosquitoes hovering over its surface, and perhaps small fish, even trout, lurking in its pools. And now the rocks and pebbles over which the brook rushes show the familiar rounded look of those stones which we know were polished by the action of water. At the foot of the mountain we may find the

forests giving place to fertile farms instead of rocky slopes.

The story of soil making goes back a long, long way into the past history of the earth. We must look back millions upon millions of years to an earth with no life, no soil, nothing but water and masses of rock. It would be too long a story to tell how all the different kinds of rocks were formed, for soil was made gradually from the rocks. Frost and heat chipped the rocks, winds blew particles against them, glaciers gouged them out and deposited the ground-up sediment in the streams formed from their melting ice. Streams of water tore their way down mountainsides and ground up particles of rock as they went. All these forces slowly but effectively did their work and helped make the first soil. Then after plants appeared on the earth, their dead bodies decayed and went to help form soil. Thus two kinds of soil could be found: that made from the original rocks and that containing the decayed bodies of plants and animals.



Wright Pierce

A mountain stream. Why are the rocks rounded?

But under the layers of humus or decayed organic matter and the various layers of loam, clay, or gravel, we

come at last to bed rock, the material out of which the original soil was made. All of these changes on the earth have taken a very long time. Nature works slowly, but Nature is always working. Everywhere the forces of running water, the wind, ice, heat, and cold, are at work changing the rocks into soil, just as they have been at work in past ages. The earth's surface is constantly changing, and some of the changes take place within our own life span.

One very interesting evidence of these changes on the earth comes from the story told by fossils, or remains of former life found imbedded in some rocks. Not only do these remains show us that very different plants and animals once lived on the earth, but they also show us that great changes in life have been brought about through the changes in climate and the alteration of the earth's surface. The purpose of this unit is to tell the story of

Wright Pierce

Which of these pebbles was taken from the brook? Which from rocks on the mountainside?

how the earth became a place fit for living things to grow on, how the living things have changed, and how and why the earth has become fitted for life today.

The great mass of rock below the mountain jutting out into the forest is a lava flow. Once it was molten lava, now it forms what kind of rock?

PROBLEM I. HOW WERE THE ROCKS FORMED?

Three Ways in Which Rocks Were Formed. Let us go out into the field to answer this question. You will find, depending upon where you happen to look, various kinds of rock. Rocks of one kind appear to be made up of pieces of different kinds of substance, all mixed up together as if a giant had stirred them all up while hot and they had cooled quickly. Probably the original rocks of the earth were formed as molten masses of semifluid material, like lava that flows from a volcano during an eruption. Such rocks are called *igneous*, of which granite is an example.

Others look as if they were formed in layers. Such rocks, like sandstone, shale, or limestone, were actually formed from particles of ground-up rock being deposited under water. Layers upon layers were made; the lower layer may have been carried down miles below the surface of the earth, and when subjected to heat, pressure, and chemical action the particles were cemented into solid

rock. Perhaps a million years later this part of the earth rose, the surface layers were worn off, and this layer of material is back at the earth's surface once more, but now solid sandstone and not loose particles. Such rocks are called *sedimentary.*

Another kind of rock seems to be in layers, but these layers are greatly curved or folded, like the rock shown in the picture. These look as if they might have been made like sedimentary rocks and then pressed together by some great force. Possibly they might have been the igneous rocks partly remelted, and pressure caused a movement so that particles appear in bands somewhat resembling layers. People who have made a study of rocks believe both of these processes have been in action and have caused these rocks to be changed from the original condition. They are called *metamorphic* rocks. Examples of such rocks are gneiss, marble, and slate.

Rocks and Minerals. Geologists call the material out of which the solid part of the earth is formed *rock.* But if you look at some rocks carefully, you will see they are

Geographical Survey, G. K. Gilbert Negative

Geographical Survey, T. N. Dale Negative

Sedimentary and metamorphic rock. How does the right-hand picture differ from the left-hand one? What seems to have happened to the metamorphic rock?

made up of particles, some large, some tiny. Each of these substances out of which rock is formed has a different chemical composition and is called a mineral. Sulphur is a mineral containing a single chemical element, while table salt or a grain of white sand is a mineral each made of two elements combined in compounds. Granite, on the other hand, is made up of several minerals in which quartz and feldspar are always present. Rocks usually contain several minerals, but some, like the rock salt, are single minerals. The name of the mineral, salt, is halite, and when freed from impurities, we use it to season our food. Mica is an interesting mineral. Some mica is white and some is black in color. It has the remarkable quality of splitting off in very thin almost transparent sheets. It is often incorrectly called isinglass. It is used as an insulator in electric devices and for windows in doors of stoves.

Rocks and Minerals Are of Different Hardness. If you take a number of different minerals, such as quartz, feldspar, mica, rock salt, talc, gypsum, and others, you

Wright Pierce

This shows how the hardest rocks (granite) may be weathered to form soil. What has probably caused this rock to break down?

will find that your knife blade will scratch some and not others. You can scratch your knife blade with quartz, while the blade will easily scratch such a mineral as talc or rock salt. Minerals, evidently, differ in hardness. They also differ in other respects, such as color, chemical composition, the kind of crystals they form, and other ways. Because of these differences, the rocks out of which they are made also greatly differ. Some are hard, others relatively soft; some strong, others brittle.

Rocks Change to Soil. If what has just been said is true, then the change from rock to soil must go on much faster in some rocks than in others. Soils also vary in different places, depending on the kind of rock they are made from. Quartz, for example, is harder than feldspar. When granite breaks down to form soil, the quartz particles, being harder, grind the rest of the rock to fine powder, while they remain as grains of pure quartz.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

hard	heat	sedimentary	ice
soft	cold	durability	clouds
softer	igneous	loose	metamorphic
rock	cut	quartz	scratch
solid	molten	soil	melting
mineral	vaporized	water	chemical
mud	solidified	air	layers

Granite is an example of an (1)____ rock which formed from a (2)____ condition. Sandstone is a (3)____ rock and was once (4)____ particles which eventually were brought into (5)____, probably through the action of (6)____. After being buried deep in the earth loose material may under the action of (7)____, pressure, and cementing by (8)____ action be changed into solid (9)____. Both sedimentary and (10)____ rocks may undergo a partial (11)____ and be changed greatly in form. This class of rock resulting is called (12)____. Most rocks are made up of two or more

minerals. Rock salt is both a (13)____ and a (14)____. Quartz is a very (15)____ mineral. It will even (16)____ steel. Rocks vary greatly in (17)____. The brittleness of rock determines in large measure how quickly it is changed to (18)____. In many places the beach sand is almost wholly (19)____ because the (20)____ rock has been ground to a powder.

STORY TEST

Ralston Has a Fine Collection of Rocks and Minerals

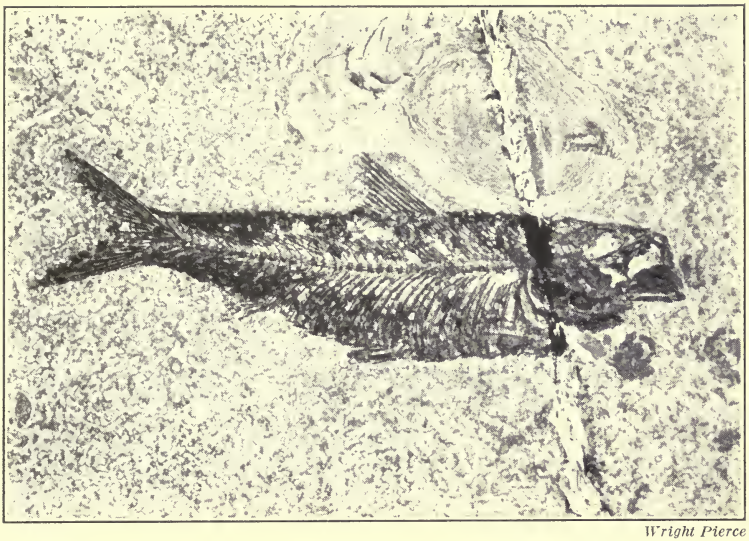
Read carefully and critically. List all the errors and suggest corrections.

It has been great fun to make this collection, and I never tire of showing them. First, I'll show you the minerals. This glass-like stone is quartz. It is quite hard but you see I can just scratch it with my knife blade. Here is a white mineral feldspar, easily scratched by quartz. It breaks with more even surface than quartz. See this beautiful specimen of isinglass. I put my knife point under a thin edge and peel off a large transparent sheet. These minerals that I have shown you all came from sedimentary rocks. This piece of marble is an igneous rock because heat helped to form it. Granite is a typical mineral that has been formed by the slow cooling of molten rock; the more slowly it cooled, the larger the crystals in it. Here is a piece of gypsum; you can scratch it with your thumb nail. This smooth pebble is found in the bed of a brook. This chip was probably broken off by ice. The colored streaks in this rock are probably due to the light which reached it while the rest was covered with soil.

A fossil fern-like plant. In what kind of rock would you look for such a fossil?

PROBLEM II. WHAT IS THE STORY OF THE FOSSILS?

What Are Fossils? Someone has likened the earth to a book whose pages tell its life story. The leaves of this book are the layers



Wright Pierce

This fossil fish lived in recent geological time. How do we know this?

of rock, and the characters we read are the imprints left by the living things that inhabited the earth in past ages. Moving water deposited sediments in oceans, ponds, and pools of streams. Plants and animals living near these places were often buried in these sediments and as time went on and the sediment became rock, the remains of the living things were preserved. Sometimes they were the undecayed parts of plants and animals, sometimes the skeleton, often only an impression, such as a footprint or a space once occupied by the soft body. Any such trace or remains of former life is called a *fossil.*

The story told us by these fossil remains is not very complete, but it is plain enough to show us a number of very interesting things. The first is that the earth has been inhabited by living things for a very, very long time. Geologists used to think it was millions of years, but they now believe it a much longer period. New ways of estimating the age of the earth have been found, one by

National Park Service

A fossil tree of the Arizona desert. These trees are found by the hundreds in some parts of the west, in some cases having been changed to agate or other semi-precious stones. This one is now held up by a concrete base.

figuring the amount of time it took to carry salt to the oceans to give them their present saltiness. This estimate is about 500,000,000 years. Another and newer estimate has just been completed by a group of scientists appointed by the National Research Council in Washington, and they, basing their calculations on radio activity of certain rocks, have estimated the age of the earth at the incredible figure of over 2,000,000,000 years.

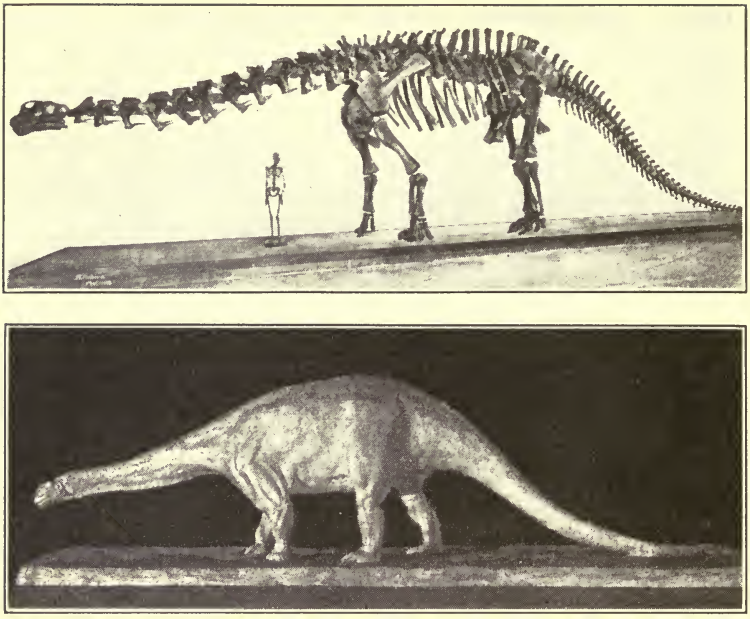
Of course life did not exist on the earth at first, and nobody knows how the first life came. But we do get this much evidence from the fossils. The very oldest igneous rocks, which we have learned were formed when the earth was very young, do not contain any fossils. The earliest evidences of life come from bacteria, and following them we find tiny plants and animals, all of which lived in water.

What Fossils Tell. The character of the fossil tells whether it was deposited in salt sea water or fresh lake

water. Land animals and the stems and leaves of plants could only be deposited close to the shore. Corals could only be buried in deposits in warm water. Plants which grow only in arctic regions indicate cold water. Thus fossils can tell something of the climate of regions of the earth millions of years ago. Fossils of salt-water life disclose the fact that there have been seas where now it is land. The relative positions of different layers of rock often tell the relative ages of the different kinds of life on the earth.

In some parts of Arizona and other places, you can visit petrified forests. Great trees which have been changed to solid rock lie here and there. Some are formed of beautiful agate or other precious materials. These trees were buried by volcanic material, and the mineral matter dissolved in the water replaced the woody fiber and preserved the form of the tree. In many parts of the country, various animal remains, such as corals, shell, and

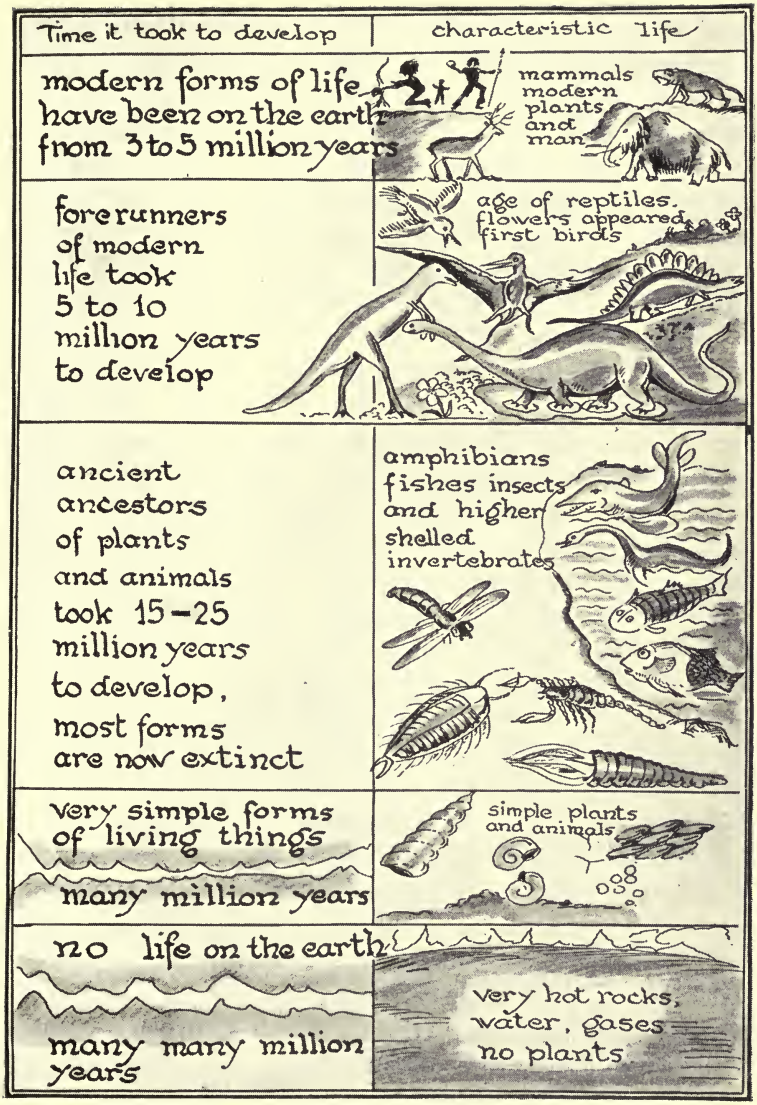
These animals were trapped in the famous tar pits of La Brea, near Los Angeles. An elephant and wolves have been caught in the soft tar and the saber-toothed tiger will soon suffer the same fate.



This huge reptile-like Brontosaurus lived on plants and grew to be 60 feet long. It must have weighed 30 to 40 tons. Notice the skeleton of the man in the upper picture.

bones, are found in the rock. In the far west, great skeletons of extinct animals have been dug up. One of these is that of a huge vegetarian called the Brontosaurus, which was 60 feet long and weighed 30 tons. But skeletons of still larger animals have been uncovered; for example, a great elephant-like creature, the Atlantosaurus, 100 feet long and weighing 100 tons. In some parts of the world the fossils of flying reptiles and even ancient insects have been discovered. Some of the dragon flies found had a wing spread of two feet.

Changes in Life on the Earth. One very evident thing comes from the study of these fossils. That is, that the earliest forms of animals were very simple. Then the earth became peopled with many water-living forms, mostly



What are a few million years in the history of this old earth?

invertebrates. Then came vertebrate animals, all water forms at first, followed by huge reptiles such as those shown in the picture. Later still we find forms of mammals much like those of recent times. Such is the wonderful collection of animals which were caught in the tar pits of La Brea, in Los Angeles, some 20,000 or 30,000 years ago. This collection includes tigers, sloths, mammoths, and many tropical forms not very different from those living today. When man came is all a guess, but it was probably a million or so years ago, a very recent time measured in the earth's history.

Plant life also has shown great changes. After the first plants appeared on land there must have been a period very favorable for plant growth. Evidently the earth had a moist, hot atmosphere, and perhaps the sun was more powerful than it now is. At any rate, there was a time, during which our coal beds were formed, that the earth must have had a growth of great fern-like and palm-like plants, which grew as tall as our modern trees. In more recent times the plants had many of the characteristics of our modern trees, and the flowering plants appeared. In general, the same story is told by both plant and animal fossils: first, that there has been continual change in the forms of life; second, that simpler forms of life came first on the earth; third, that the oldest forms of life are found in the oldest rocks which are buried deeper than the more recent forms; fourth, that great changes in climate and surface conditions have taken place; and fifth, that we can construct a very good picture of past life on the earth by piecing together all the evidence as we see in the picture on page 225.

It is pretty evident that life began in the water; that bacteria and simple plants were the first living things; that many forms which once existed have disappeared, and that our present forms of life are still changing.

SELF-TESTING EXERCISE

Select from the following list the words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

2,000,000,000	oldest	not	history
sediments	youngest	inhabit	very
500,000	does	animals	rock
sand	do	marble	mud
dead	often	plants	fossil
living	sandstone	plant	water
lived	never	petrified	earth

Sedimentary rocks originated from (1)____ deposited in (2)____. After (3)____ things came to (4)____ the earth, it (5)____ happened that plants or (6)____ would be buried in the (7)____. After the (8)____ hardened into (9)____ it might preserve evidence of the (10)____ or animal. Any evidence of a living thing preserved in this way in (11)____ is called a (12)____. It is believed the earth is at least (13)____ years old, but living things have not always (14)____ here. Igneous rocks which are the type of the (15)____ rocks on the earth (16)____ (17)____ contain fossils. Sedimentary rocks (18)____ (19)____ contain fossils from which we read the (20)____ of life on the earth.

STORY TEST

Herbert Has Had Fine Opportunities for Field Observation

Read carefully and critically. List all the errors and suggest corrections.

Last summer I was lucky enough to be invited on an auto camping trip with my chum. His father, a science teacher, was one of the party. In the Connecticut valley in Massachusetts we saw great 3-toe footprints in beds of sandstone. There were no bones of the animal but it was a fossil just the same. In Barre, Vermont, we visited the world-famous granite quarries. We saw toads there that the men said jumped out of hollow places when they split blocks of granite out of the ledges. The toads must have been living fossils. In northern New York we saw smoothed rocks with scratches and grooves all running in the same direction. These scratches were made by the glacier thousands of years ago, and since they are records of what happened long ago, they are fossils. In western Pennsylvania we broke off slabs of limestone and found many excellent fossil shells. In a coal deposit we found the imprint of a tree showing clearly the markings on the bark.

In one of the Indiana marble quarries we found splendid shells of water animals and the skeleton of a fish. You doubtless remember that marble is a metamorphic variety of limestone and so shows the same fossils that limestone would.

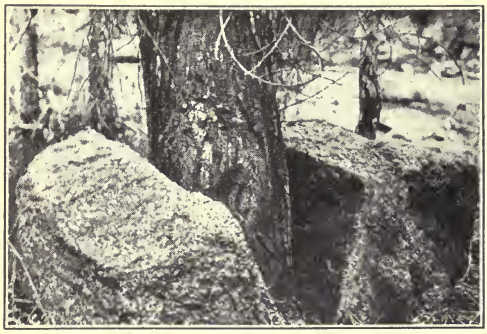
PROBLEM III. HOW IS SOIL MADE?

Soil Is Rock. From what we have learned, we can see that soil is formed from rock. There are many agents at work, and this work is going on right under our eyes. Take a rocky ledge such as is shown in the cut. Beneath this ledge is a slope of broken pieces of rock, some of which are small enough to make a coarse soil. The rock breaks down to form this slope of fragments, called a talus. But what causes it to do this? Evidently the forces of air, heat, cold, water, and gravity are at work. Any changes in rocks brought about by changes in weather or the atmosphere are called *weathering.*

What kind of rock is shown here? Find the talus slope. How would you say rocks form soil?

Mechanical Weathering. Some rocks are broken by the action of frost and the sun's heat. We know that frozen water occupies almost 10 per cent more space than in a liquid state. Try the experiment of freezing a corked bottle full of water and see what happens. When water inclosed in a crack

in rock freezes, the ice formed presses with a force of 2000 pounds per square inch on the rock surrounding it. No wonder the rock chips off! When we add the heat of the sun to the action of frost, and remember that on the desert there may be differences of 100° between the day and night temperature, we can see why the outside of the rock becomes larger than the inside and strain results which causes it to crack and break.



Amer. Mus. of Nat. Hist.

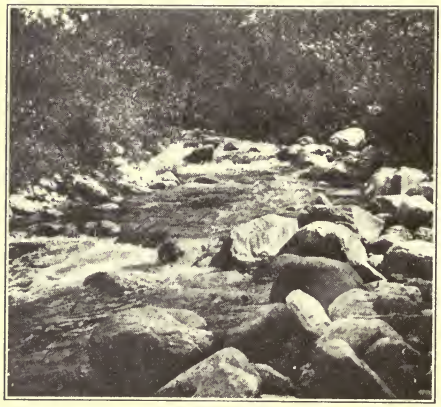
This tree started in a crack in a granite rock and has exerted force enough to split it.

The tree in the picture has split the rock just as a wedge will split a block of wood. As trees grow, their roots press the rock apart more and more and thus allow the other agents of weathering to act upon it. Burrowing animals, earthworms, ground squirrels, gophers, and woodchucks break up the soil into finer particles. Wind and rain also help to break down rocky soil and distribute it so that other agencies will also act on it.

Chemical Weathering. We do not realize that rocks decay, but such is the case. Pure water will not have much effect upon rock, but add to it a little acid and it will soon eat away limestone rock. Plants give off acid through their roots, thus causing certain kinds of rock to break down. Then oxygen and carbon dioxide in rain water cause rocks to oxidize and decay, or the rock may dissolve. The beautiful red and brown coloring of rocks, such as at Bryce, Zion, or in the Grand Canyon of the Colorado River, is caused by the action of oxygen and water.

Demonstration 1. Solution of Limestone.

Pass carbon dioxide into a jar of limewater. What happens? This substance has the same composition as limestone. Now continue to pass the carbon dioxide into the jar, and you will see the white substance disappear. It has been dissolved by the extra carbon dioxide in the water and has passed into solution.



Streams play an important part in changing the surface of the land. Explain how they do this.

Erosion. You have all seen gullies cut in the bank of the river after a heavy shower, and have noticed that soil is carried down by the water and distributed in a layer at the foot of the gulley. A mountain stream shows the same effect on a large scale. This wearing away and carrying off of material is called *erosion*. Our mountains

Wright Pierce

Wind has caused these holes in the rock. How could it do this? Read page 231.

are being leveled, our river valleys cut deeper, and soil is being deposited far from where it was originally made from rock — all by this force of erosion. Erosion is a leveler which is carrying mountains into the oceans, and producing many other changes in land forms over the surface of the earth. Erosion in its broadest meaning includes weathering.

Carlsbad Chamber of Commerce

A view in the Carlsbad Caverns. Notice the stalactites and stalagmites formed from minerals once held in solution in water.

Erosion by Water. The mountains of Switzerland and many of our western peaks are huge rock masses which are being worn slowly away by water. The force of the water loosens the big bowlders, rolls rocks downstream, rubbing one against another, and causing them to be ground into powder. In many a mountain stream today we may see this powdered material going down with the turbid water to be deposited at the river's mouth in the form of a delta.

Erosion by Wind. In many parts of the world, the wind has an important part in soil making. In some parts of western United States, the wind drives millions of particles of sand against the sandstone cliffs with such force that they are worn down and hollowed out by this natural "sand blast."

Erosion by Solution. You know that sugar placed in lemonade soon dissolves in it and disappears, but the sugar may be tasted in all parts of the glass of lemonade. The sugar passes from the solid to the liquid state by a physical process known as solution. If a substance dissolves in a liquid completely, we say the substance is soluble and that we have a solution. Rain water, although perfectly pure as it starts to fall from the clouds, dissolves air in falling and after soaking into the ground may soon take up mineral matter into solution. As we have seen, certain minerals, particularly the compounds of calcium and magnesium, are slightly soluble in water which contains CO_2. In some parts of the country, great gaps and caves have been formed underground where limestone has been dissolved and removed by running water.

Old Faithful is so called because it always erupts on time. Can you find out what causes this action?

Hot Springs and Geysers. Underground water which comes to the surface in springs may contain mineral matter in solution. The mineral springs of the United States are valued at millions of dollars. Many of these waters are claimed to have medicinal properties. In regions where volcanic action has been

The Chisana Glacier, Alaska. Glaciers carry with them ground-up rocks and stones, which may be deposited far from where they were eroded. Explain the meaning of the dark line running up the right-hand side of this glacier.

recent, underground waters may be heated by beds of lava which are still hot. Here we find hot springs. If the water, instead of flowing regularly, is erupted intermittently, the spring is called a geyser. Since hot water dissolves mineral matter more readily than cold water, much matter is brought by hot springs to the surface and deposited as the water cools. Hot springs are found in several parts of the world, most of them being in Yellowstone National Park. Here there are about 3000 geysers, of which Old Faithful deserves its name, for it erupts about once every hour, when it throws up about 700,000 gallons of water.

Erosion by Glaciers. A great ice sheet covers Greenland today. The pressure from the continued accumulation of snow causes a slow movement of this vast sheet of ice into the ocean, and from time to time fragments on the edges break off and form icebergs. It is believed that many thousands of years ago a great sheet of ice moved down from the north and covered a large part of

The Delaware Water Gap. Are these mountains old or young? How do you know?

northern United States as far as the Missouri and Ohio rivers. The tremendous weight of ice, thousands of feet deep, scoured and broke off projecting hilltops and mountain peaks. The stone fragments moving along under the ice were efficient cutting tools for grinding other rocks underneath. At the front of the ice sheet streams of water poured out, carrying dirt and rocks, which were deposited in layers, just as material transported by our rivers is being deposited today.

How We Can Use Our Knowledge about Erosion. If you were fortunate enough to take a trip across our continent, you would be able to see some of the results of the various agents and to interpret them as you went along. In the far West you would pass through deep, rocky canyons having steep, jagged sides. We recognize these and the sharp rugged mountains of the West as the results of quite recent erosion, as geological time goes. We would see great deserts of wind-blown earth and sand and many groups of fantastic rocks carved and etched by the

blowing sand. We might even have a sandstorm and have the windshield of our car etched and pitted by the wind-driven grains. And as we got near the eastern coast, we would find mountains again wooded to their summits, mountains with smooth rounded outlines which the geologists tell us show that they are very, very old and have had time to lose their angular steep sides so characteristic of the younger bare mountains of the far West. In some places we would find soil just where the forces of weathering had produced it. This is called *residual* soil. In other places the soil has been brought by moving ice, water, or wind and is called *transported* soil.

SELF-TESTING EXERCISE

Select from the following list the words which best fill the spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

springs	more	ice	colder	transported
wells	less	steam	outside	geysers
rivers	greatest	water	inside	weathered
expand	mechanical	cooling	soil	residual
contract	chemical	heating	rocks	erosion
move	air	hotter	lava	weathering
iron	oxygen	separation	dissolved	dioxide

Ice occupies (1)____ space than the water from which it is formed. Freezing (2)____ is an important (3)____ agent in breaking down rocks in the process of (4)____ formation. When the sun's rays beat down upon a rock, the (5)____ layers become (6)____ than those below and as they (7)____ they tend to loosen. Alternate heating and (8)____ finally results in the (9)____ of fragments. Limestone rock is (10)____ by water containing carbon (11)____. Rocks that contain only a minute quantity of iron remain unchanged deep in the earth, but when exposed to the air, turn brown and rusty because the (12)____ of the (13)____ has combined with the (14)____ of the rock. Such (15)____ rock crumbles easily, producing (16)____. The wearing down of rocks and transportation of the material is called (17)____. Water is a powerful agent of (18)____. Underground waters in some parts

of the earth are heated by subterranean (19)____ beds. These waters bring mineral matter to the surface in boiling (20)____ and (21)____. (22)____ soil is that which remains in the place where it was produced. Soil moved to other localities by moving ice or water is called a (23)____ soil.

STORY TEST

An Extract from Annette's Notebook on Soils

Read carefully and critically. List all the errors and suggest corrections.

Soil has not always existed on the earth; it is therefore not an essential factor of our environment. Before soil was formed, the solid part of the earth was entirely sedimentary rock. Rocks decay, crumble, and are reduced to soil through the agencies of weathering but also through mechanical action of wind, water, and ice. Perhaps you have seen how granite steps wear away more quickly than marble steps. Our finest buildings quite often have marble floors because of their durability. When water contains nitrogen from the air in solution, it will dissolve limestone and marble. Much soil in northern United States is transported soil brought by running water and ice. Rocks on mountains are more exposed than elsewhere, and for that reason the soil is deeper on mountains than in valleys. Many rocks are eroded just by the action of the oxygen of the air combining with the iron in the rocks. There is still heat in the interior of the earth and in some places underground water is made to boil, causing hot springs and geysers. These waters have nothing to do with soil formation, however; the water may spout out and flow back, or it may flow continually as in any cold-water spring.

PROBLEM IV. WHAT SOILS ARE BEST FOR AGRICULTURE?

Differences in Soils. We have seen that soil is weathered rock, that either remains in place, or is carried away by erosion. When water transports soil, it tends to sort out and distribute different-sized particles to different places. But if the volume and speed of the water change, a layer of fine material may be placed upon a layer of coarse material, or a fine-grained sediment may be laid upon a

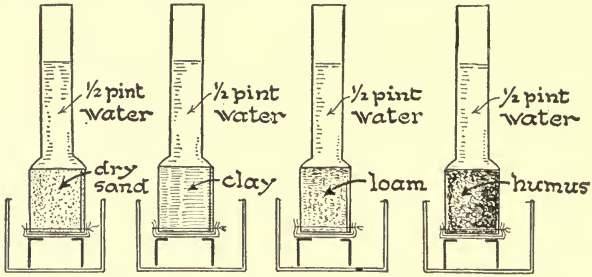
coarse one. The layers of sediment, too, may vary in composition, depending upon the kind of rock from which they are made. We know that sandstone forms sandy soils, but we may not know that clayey soils come from the breaking down of shales and feldspars. Igneous and metamorphic rocks may yield both clay and sand. Sand by itself makes a barren soil because there is not much in it except glass-like silica or quartz. Plants need a large variety of elements. Limestone produces a limestone soil which is usually very fertile. The soils from feldspar furnish potassium, sodium, calcium, magnesium, and iron, making a rich soil. But if it makes a compact clay, it is too wet and lacks air for good crops. Mixed with sand, it makes a good soil for crops. Soils, therefore, differ in different parts of the country, depending upon the rocks found there, or transported there. The lower Mississippi region is very fertile because of the rich soil brought down in floods and deposited where the river overflows its banks.

Kinds of Soils. Those of us who have gardens know that the fertility of our plot depends largely on the soil which makes it up. Most soils may be divided into the following general groups: Gravel, composed of a mixture of coarse sand and pebbles; sand, largely made of quartz, produced from granite or sandstone; clay, rock ground up so fine that it is not gritty when rubbed between the fingers, feels sticky, molds rather easily with water, and becomes hard when dry; silt, particles too fine to class as sand and too coarse to be a clay; loam, a combination 50 per cent of sand and 50 per cent clay and silt together; humus, largely decayed plant and animal matter. For gardens the latter material is considered quite necessary.

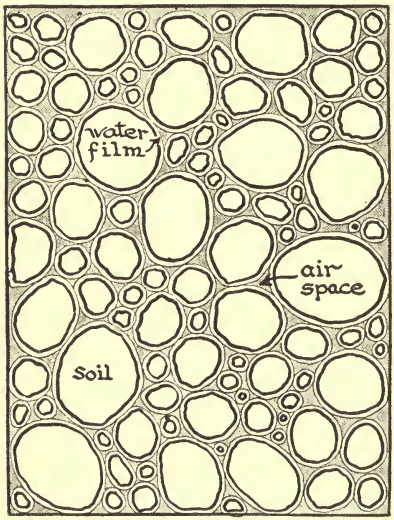
Demonstration 2. Water in Soil.

Materials. Four student-lamp chimneys; equal volumes of dry sand, clay, loam, and humus. Tie two or three thicknesses of

cheesecloth over the lower end of each chimney. Invert them and pour in ½ pint of water on the soil in each. Catch the liquid that passes through and measure it. Which soil holds water best?



Water and Air in the Soil. You are all familiar with the fact that coffee creeps up on a lump of sugar placed partly in it, and that oil rises in a lamp wick. You may wish to try the experiment on capillarity described below. Have four very fine tubes, each having a different hole of different diameter running through them. These are placed side by side in a dish of water. The smaller the diameter of the tube, the higher the water will rise in it. This rise of fluids against the force of gravity is called *capillarity*. Soil, if examined under a magnifying glass, is found to be made up of many particles of different sizes, each particle holding around it a film of water, as shown in the diagram. Water rises through the



Each particle of soil is surrounded by a film of water and air spaces are found between the particles. The artist has exaggerated these to show how air and water are held in the soil.

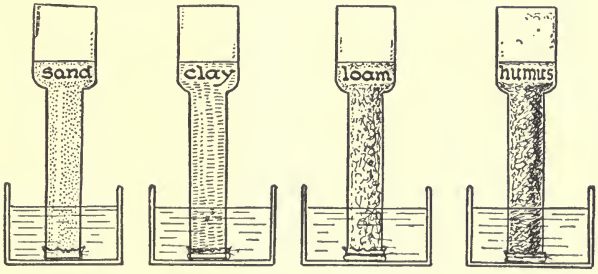
narrow spaces between the soil particles by capillary action, and thus it is found in the soil not far from the surface.

The loose, porous structure of the soil allows a certain amount of air to remain in the spaces. Plants breathe, since they need the oxygen of the air just as much as we do. And since the delicate roots of plants absorb air as well as water, porosity of soil is very necessary for the garden.

Demonstration 3. What Types of Soil Favor Capillary Action?

Materials. Lamp chimneys, four types of soil as in last experiment, large shallow pan.

Methods. Place equal amounts of different types of dry soil in different chimneys. Pack the soil fairly tight. Set each chimney in a pan filled with water to a depth of an inch. Notice the water rising in the different soils. In which soil does it rise fastest? Highest?

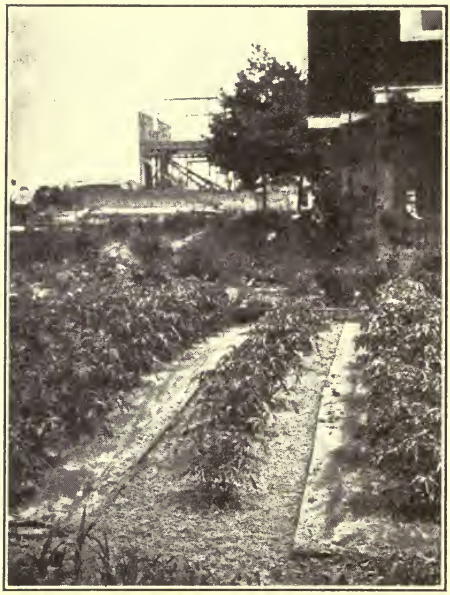


Conclusion. Which soil do you think is best adapted to carry moisture?

Effects of Cultivation on Soil. In order to keep the soil from being packed too firm and hard, and thus prevent air from passing into it readily, we *cultivate,* or break up, the top layer of the soil either by hoeing, raking, and harrowing, or by means of a cultivator. Cultivation crumbles the soil and allows the plant roots to creep through it more easily. It breaks up the soil particles so that water can dissolve out the materials which the plants use for

food and allows air to pass through the soil. By either a loose surface mulch or by a paper mulch as seen below water is more easily kept in the garden soil.

Mulches. Farmers have learned by experience the value of cultivating the surface of the ground to a depth of three or four inches, making a so-called dust mulch over the surface. If the surface becomes hard and cracks, the water will evaporate very quickly. By placing a finely powdered layer of soil over the top of the field, water will be held in it for a much longer period. In some parts of the West where rain is very infrequent, farmers practice what is known as dry farming. To do this they must first plow the ground deep so that when the rain comes the ground will be ready to soak it up and retain it. Then the surface layer of the ground must be constantly worked and turned over to form a surface mulch. This is done by making a layer of very finely pulverized soil on top. The latest method of keeping water in the soil is seen in the picture. Here a layer of heavy paper is placed over the soil in which the plants are growing and this prevents the water



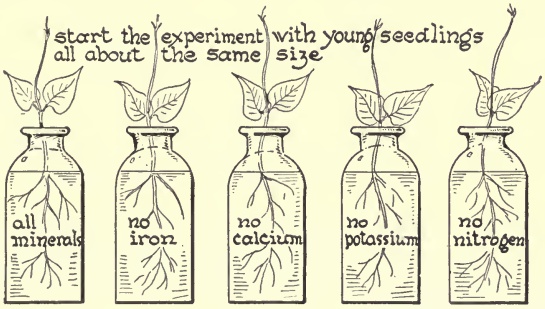
U. S. Dept. of Agr.

Paper mulch. Experiments have shown that moisture is best kept in the ground by means of a paper mulch such as is seen in this picture. Are there any evidences of its use shown here?

in the soil from passing out by evaporation. In some places farmers can only grow one crop every other year because of the small amount of water. In such cases, the farmer keeps half of his land under cultivation, and the other half covered with straw or a surface mulch so as to allow it to accumulate water. Thus a crop is raised every two years without the addition of more moisture than the soil holds by reason of its mulch.

Demonstration 4. To Show That Certain Mineral Substances Are Needed for Plant Life.

For this experiment use five wide-mouth bottles: one containing a nutrient solution with all the necessary minerals, and each of the other four containing a nutrient solution [1] lacking



either iron, calcium, potassium, or nitrogen. In these bottles place young seedlings, and allow them to grow for several weeks. Note the results. What mineral substances are necessary for the growth of green plants?

[1] The control nutrient solution is made up as follows:

Distilled water	1000 to 1500 grams
Potassium nitrate	1.0 gram
Magnesium sulphate	0.5 gram
Calcium sulphate	0.5 gram
Calcium or potassium phosphate	0.5 gram

To this solution a trace of some iron salt, as ferric phosphate, should be added.

If you do not have the facilities for making the solutions needed, have a druggist weigh out the required amounts of the several different substances and add to distilled water, as suggested in the experiment.

Elements Used by Plants. There are a number of elements that are found necessary for the growth of plants. Three of these, carbon, nitrogen, and oxygen, are found in the air, while phosphorus, potassium, magnesium, calcium, iron, and sulphur are found in soils. In order for plants to grow, these elements must be in the form of soluble compounds so that they can be absorbed through the roots of the plants. Iron aids in making the leaves green. Potassium helps the plant to make food substances. Phosphorus helps the root to grow and seed to ripen. Calcium aids the roots by separating the substances in the soil from other materials so that they can be readily absorbed. Nitrogen is necessary because of the relatively large amount used in the living matter of plants.

Acid and Alkaline Soil. In the far West, alkali soil is often found, especially in desert regions. If such regions get water through irrigation and are used for agriculture, as much as possible of the alkali must be removed from

Wright Pierce

This is a dried-up lake bed which is impregnated with alkali. In the rainy season this is a lake so impregnated with alkali that the water is not fit for use.

the soil or crops will not grow. This is done by flooding and then draining the land, thus washing out some of the alkali. In some parts of the country the soil becomes acid and this prevents the growth of crops. In such cases lime is used to neutralize the acid and thus sweeten the soil.

SELF-TESTING EXERCISE

Select from the following list the words which best fill the spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

gravel	black	decreases	fertilizers
loam	dry	increases	capillary
clay	wet	enrich	lime
humus	air	ability	acid
sand	scarce	checked	water
silt	evaporates	abundant	mulch
red	condenses	dissolves	conserves

A good garden soil contains (1)____, composed largely of fine grains of quartz, (2)____, which is extremely fine, and (3)____ which contains organic compounds and gives the (4)____ color to a rich soil. A compact soil neither allows (5)____ to pass up or down readily nor does it allow space for (6)____ which is necessary for the roots of most plants. Water creeps up through minute crevices by (7)____ action. The movement of water is (8)____ by cultivation. Packing a porous soil (9)____ the loss of water from the surface where it (10)____ and passes into the (11)____. Loosening the particles and increasing the air spaces within the soil (12)____ the loss of water which (13)____ if it reaches the surface. Cultivation of the surface produces a (14)____ that (15)____ moisture. Soils long used lose their (16)____ to produce (17)____ crops unless (18)____ are added to (19)____ them. Acid soils are sweetened by the addition of (20)____.

STORY TEST

Will Archie Have a Good Indoor Garden?

Read carefully and critically. List all the errors and suggest corrections.

I plan to have an indoor garden. I have a large flat pan to hold the soil. It was a problem to know what soil to select. I went to a sand pit where there were all kinds. The sand was

gritty, had sharp edges, and I was afraid it would injure the seeds so I discarded that. There was some "leaf mold," as the man there called it, at the very top under some shrubs. He recommended that, but I didn't want the mold on my seeds. The black earth extending down a foot from the top looked too dirty so I discarded that. There was a streak of gravel, but I knew tiny roots couldn't penetrate the pebbles. Then I saw two more kinds of soil. One was a yellowish sand that looked good to me, but our experiment showed it was porous and so when I watered the plants the water would run through. The last was a bed of clay. I could see that this was fine grained. It was in such lumps I could hardly get it out. I could easily see that if I watered it that the water would have hard work to get out, so I chose the clay. I also knew that it was richer in food value for plants than sand is.

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come out of the applications of the facts you have learned and the demonstrations you have seen. These big ideas we call generalizations. For this unit they are as follows:

1. The surface of the earth is being constantly changed by the forces of water, wind, heat, cold, and other agents.
2. These changes are always going on night and day, winter and summer.
3. We can recognize whether these changes are recent or very old by the appearance of the earth's surface.
4. We know that different forms of life once inhabited the earth because of remains in the rocks called fossils.
5. Soil has been formed and now is being formed by the weathering and erosion of rocks.
6. Plants use the elements of the soil in order to live.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations; then, using the generalization, the material in the text, and in addition everything you have read, seen, or done yourself, make a summary outline for your workbook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of the statements you believe to be correct. Under the second place all the numbers you believe to be incorrect. Your grade = right answers* $\times 2\frac{1}{2}$.

I. **A rock should always be classified as igneous if it:** (1) will scratch glass; (2) is made of crystalline minerals; (3) is made up of hard layers; (4) is made of granite; (5) contains quartz and feldspar.

II. **The following rocks were formed by cooling from a molten state:** (6) limestone; (7) sandstone; (8) granite; (9) marble; (10) fossil-bearing rock.

III. **The land surface of the earth is being leveled by many agents, among them are:** (11) ice; (12) running water; (13) gravity; (14) the changing phases of the moon; (15) wind.

IV. **The presence of fossils in the rocks:** (16) makes it possible to tell the age of the earth; (17) shows when granite was first formed; (18) gives a record of much of the early plant and animal life; (19) shows that there was life on the earth before there was soil; (20) shows that the size of animals on the earth became larger and larger with the passing of time.

V. **Soils which are able to retain moisture are:** (21) composed of much coarse gravel; (22) mixtures of sand and clay with surface freshly rolled; (23) mixtures of sand and clay with the surface layer cultivated; (24) those having the surface covered with thick paper; (25) those on which commercial fertilizers are used.

VI. **These things contribute to soil-making:** (26) heat and cold; (27) solution by water; (28) mechanical action of water; (29) movement of glaciers; (30) icebergs.

VII. **A good soil for the garden must:** (31) contain 90 per cent quartz sand; (32) have a large variety of metals in it; (33) contain both moisture and air; (34) be porous; (35) be compact like clay.

VIII. **Water may cause erosion by:** (36) mechanical grinding action; (37) evaporation from rivers; (38) solution aided by carbon dioxide; (39) hot water in geysers; (40) wave action.

THOUGHT QUESTIONS

1. What agencies have been at work in your locality to produce soil? How have they done their work?
2. You live in a limestone region and one day find a small cave in a limestone ledge. How would you account for its presence there?

3. You find a small bed of fossil clam shells near your home. What kind of rocks do you expect to find above and below them?

4. Classify the following agents as chemical, or mechanical: frost, wind, lightning, oxidation, rain, acids in soil, plants, carbon dioxide.

5. If you were to study your locality to find evidence of the action of glaciers, what would you look for?

6. How do the farmers in your locality aid nature in the production of crops?

7. What forces and agencies in your locality make plant life possible?

REPORTS UPON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. Present-day glaciers of the world.
3. How a river makes soil.
4. The varieties of rock in my state.
5. My visit to the museum to study minerals.

SCIENCE RECREATION

1. Make a collection of minerals and arrange them according to their hardness; try the scratch test. The scale of hardness for minerals is:

1. Talc — easily scratched by fingernail. 2. Gypsum — scratched by fingernail, but not easily. 3. Calcite — scratched easily with knife point, but not with fingernail. 4. Fluorite — scratched with knife, but not easily. Does not scratch glass. 5. Apatite — scratched with knife. Scratches glass with difficulty. 6. Felspar — will scratch glass easily. Can be scratched with knife with difficulty. 7. Quartz — will scratch glass easily. Cannot be scratched with knife. 8. Topaz — harder than quartz. Is scratched by corundum and diamond. 9. Corundum — harder than topaz. Is scratched by diamond. 10. Diamond — hardest mineral. Is scratched by none, but will scratch all others.

2. Make a collection of pictures taken from travel folders illustrating some of the work of erosion in this country.

3. If you live in a glaciated region, make a report on the effect of glaciers on your township.

4. (*a*) Make a trip into the country to study the effect of water erosion. How do gullies which have recently been made differ from the older ones in shape? Make two cross-sections on graph paper for your notebook to show this difference. If you live in a hilly country, try to see if all you noted in the gully can be applied to the valleys cut by streams between the hills.

(*b*) Make several excursions into the surrounding country and try to find as many effects of weathering as you can. Write up your findings in your notebook.

5. Show in any way you can that soil is a mixture and not a chemical compound.

SCIENCE CLUB ACTIVITIES

1. Have a meeting devoted to a field trip. Collect different specimens of rock found in your community. Bring them, and any other specimens of rocks which you may have, to school for laboratory study. Record in your notebook where each specimen was found. If you live in a part of the country where rocks are abundant, note where they come out of the ground. Do they lie in layers? If so, look for the remains of impressions of plants and animals in them.

2. Organize a collecting trip to get rocks and minerals for the school museum. Label and classify them.

3. If you live in a region containing sand dunes, make a field trip out there and report back to the club on how dunes are built.

4. Plan a meeting at which the program will consist of reports made by teachers or pupils who have visited some of the National Parks.

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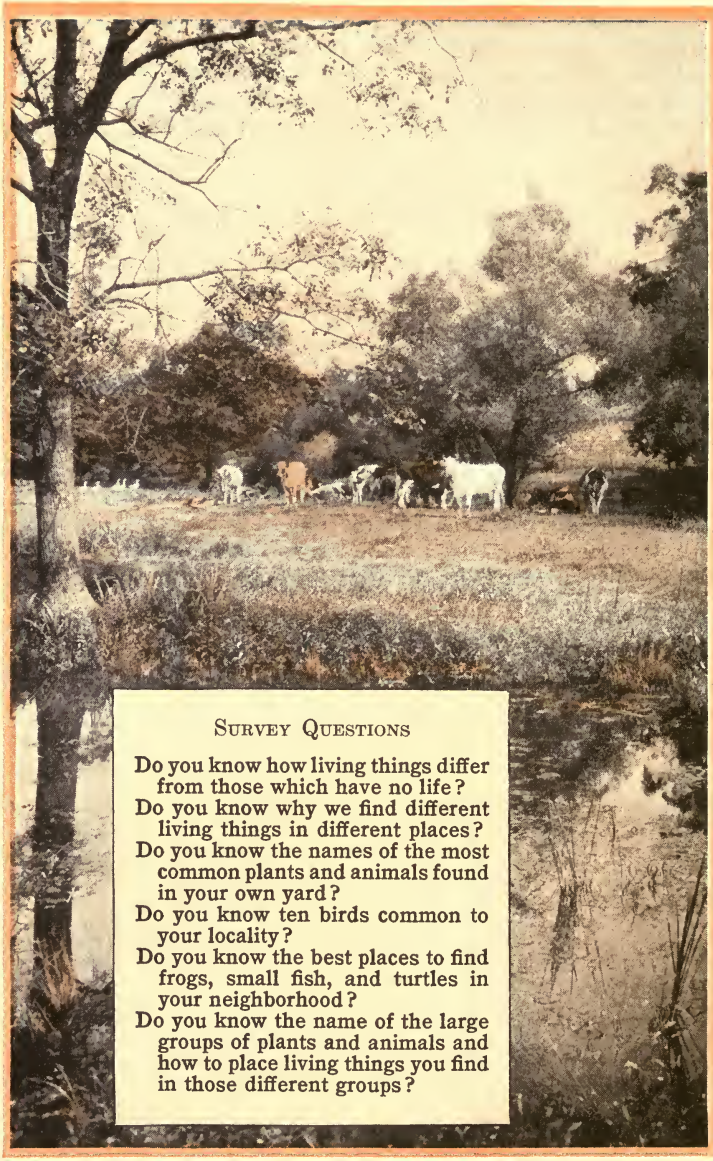


Survey Questions

Do you know how living things differ from those which have no life?

Do you know why we find different living things in different places?

Do you know the names of the most common plants and animals found in your own yard?

Do you know ten birds common to your locality?

Do you know the best places to find frogs, small fish, and turtles in your neighborhood?

Do you know the name of the large groups of plants and animals and how to place living things you find in those different groups?

Central R. R. of N. J.

UNIT X

LIVING THINGS IN THEIR ENVIRONMENT

PREVIEW

What is being alive? You know what your dog or cat does and what you do every day. You eat, sleep, move about, and play. But when it comes to really knowing what life is, we cannot tell very much about it. You know that you and your pet eat food, digest it, use it somehow to release energy and to grow, and that you are able to get rid of harmful wastes. You know that animals and plants are able to form new living things like themselves. But it is hard for a beginner in science to know much about what life really is, for that is a problem that has been troubling scientists for a good many years.

Scientists say that everything living or nonliving is in the long run a manifestation of electricity; that the matter out of which all living or nonliving stuff is composed is made up of unlike units, electrons and protons; and that every change in nature is due to the action and interaction of these particles. But when you have heard this statement and even seen demonstrations which show it to be true, you still cannot understand what it means.

So it is with life. We may talk very learnedly about it and have all kinds of theories concerning it, but we really have to go back to its manifestations — to what it does rather than to what it is — if we are to try to understand much about it. About all we can say is this: that living things show their aliveness, first, by being *sensitive*. They respond or react to the stimuli of their environment. You

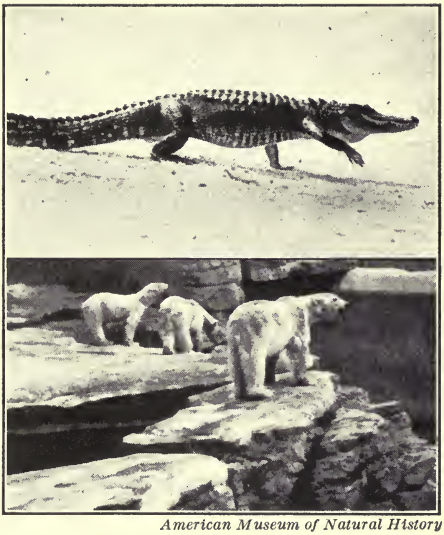
can think of hundreds of ways in which living things respond to stimuli. Roots grow towards water, leaves and stems turn to the light, earthworms seek darkness, and moths fly toward a bright light. All the forces of the environment influence us and we make responses. See how many of your own daily acts are actual responses to stimuli. Think of a pickle and see what happens. Do you know why your mouth watered? Ask your teacher to explain or read about it in some physiology.

Wright Pierce

This plant was photographed after having been placed in bright sunlight for six hours. Are green plants sensitive?

Did you ever think of the many kinds of living things everywhere around us? Life is everywhere — birds and insects in the air, fish and frogs in the water, animals and plants on the land, and even in the soil. A careful survey of a square foot of earth will show it teeming with life, most of it microscopic. You also must have wondered why certain plants and animals are found living in swamps or ponds, while others, quite different, are found in the woods or fields. Why do we find polar bears and seals in the arctic regions and lions and tigers in the tropics? Why is it that there are no trees on the tops of the mountains and plenty of trees further down the slopes? Why is it that the desert plants and animals differ so greatly

from those that live in the water? Why do we find such different animals along the coast of the seashore from those we find on the shores of inland lakes?

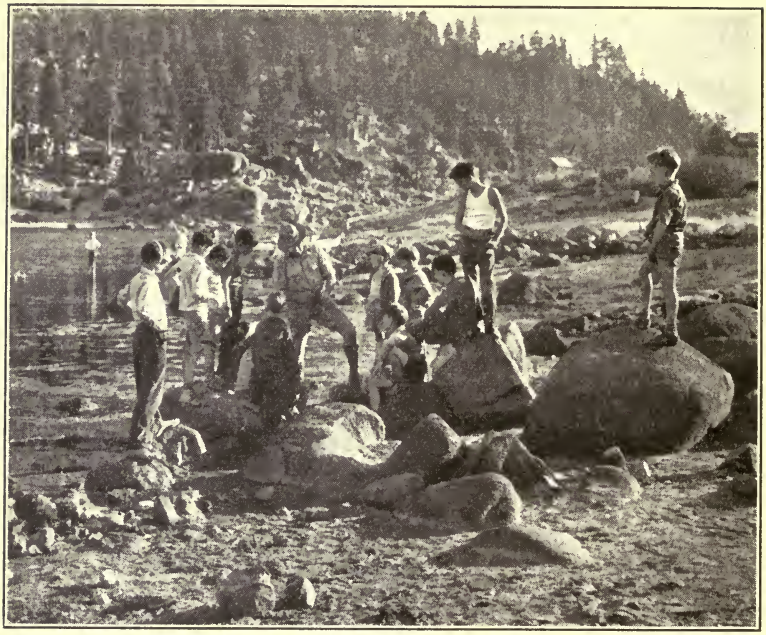


American Museum of Natural History

What adaptations can you find that fit these animals to live in different environments? In what respect are their environments similar?

If you really think about this, you cannot escape realizing that this living of different things in different places must have something to do with fitness or adaptation. If a fish has gills instead of lungs, it will live in the water, and if a bird has wings instead of front legs, it can fly. Well, you are "warm," as they say in guessing games. But there is more to the problem than this. We would have to ask how these adaptations were brought about and why certain plants and animals were always found living together in certain localities and not in others. We would find that most of our answers depend upon that characteristic which living things have of reacting to stimuli.

Another thing that boys and girls want to know about living things is the names of some of the plants and animals that are found in certain localities that they are likely to visit. We want to know what animals we will find in the ponds near at home, what plants and animals we are likely to see in a field trip to the mountains or the shore, what plants we can best use in our home gardens, what common birds can be persuaded to nest in our home



A field trip to the shore. After you have finished this unit come back to this picture and tell what forms of life the group will probably find in this place.

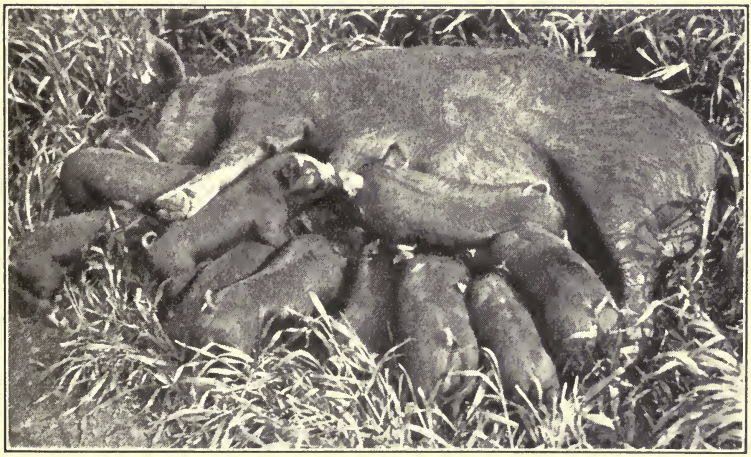
grounds, and how we can best attract them. All these and many other questions come into the minds of boys and girls when they think about the living things that are their neighbors.

PROBLEM 1. WHAT IS BEING ALIVE?

Some Beliefs about How Life Originated. On the other hand, we know a good deal about what living things do and how they differ from things that are not alive. For thousands of years people thought that living things, such as flies, bees, or other insects, were formed out of the rotting flesh of animals. The Bible quotes such a belief when it gives Samson's riddle: "Out of the eater came forth meat and out of the strong came forth sweetness."

Samson saw some little flies coming out of the decaying carcass of a lion. He thought the flies were bees and that they arose spontaneously from the lion's body — hence the riddle. This belief that living things arose spontaneously was held for many centuries, and it was not until the time of Louis Pasteur,[1] the great French scientist, who knew so much about bacteria, that this belief was finally proved false by a series of experiments. Now we know that for a thing to be alive it must come from another thing of its own kind that was alive. *Life comes from life.* We all know that chickens lay eggs from which little chicks are hatched and that plants form seeds which under favorable conditions grow into plants like those which formed the seeds. Life is like a stream, it flows on and on.

Living Things Grow. You may have perhaps made rock candy and noticed that as the sugar solution dried out, crystals formed on the string. These were formed from the sugar in the solution. The crystals grew by

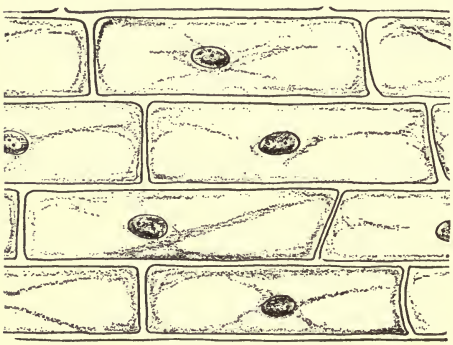


Life comes from life. *J. C. Allen*

[1] Pasteur (pȧ'stêr'), Louis (1822–1895), French biologist and chemist.

adding sugar from the outside. Living things grow — not from the outside, like crystals of sugar or ice, or the beautiful stalactites in a cave, but from the inside. As we shall see later, living things have the power to take in food and change it to the living stuff out of which they are made.

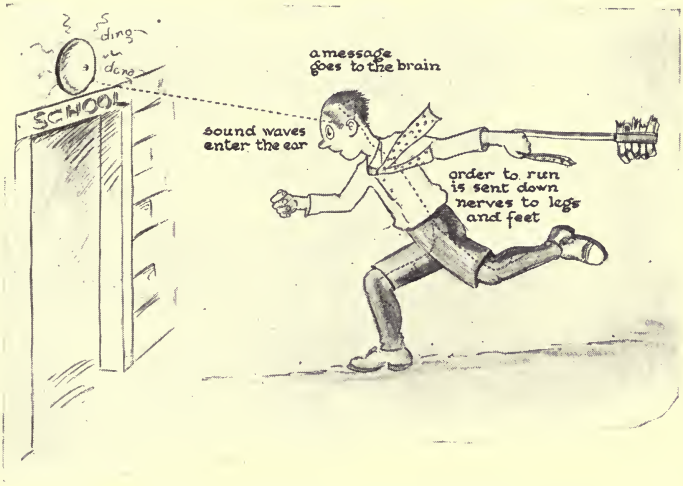
Living Things Are Built out of Cells. Another characteristic of living things is that they are made up of tiny units of material called *cells*. If very thin slices of a plant stem or bits of onion skin be examined under a microscope, they will be seen to be made up of tiny structures such as you see in the diagram. These cells have various characteristic shapes in animals and plants, but they are always very small. They grow by dividing, forming groups of like cells, to which we give the name *tissues*. In the stem of a plant we find several different forms of cells, some with heavy walls, so that they may support the stem, some lengthened out to form tubes through which the sap may pass, still others soft and dividing rapidly. The stem is growing fast in the region where these soft, rapidly dividing cells are formed, for living things grow in size by the increase in the number of their cells.



The cells of onion skin seen under a compound microscope. The oval structures in the cells are the nuclei. How many nuclei (singular, nucleus) to each cell?

Living Things Are Responsive. Then living things are responsive to conditions outside of themselves. A dog comes when you call him, a plant turns toward the source

of light, we hear the sound of the gong that marks the passing of classes and respond to its stimulus by going to the next class. Life is said to be a series of responses to stimuli. But nonliving things do not show this ability. You could talk all day to a stone and it would never move.



Living things are responsive. Prove it from this diagram.

Life Depends on the Environment. Life seems to depend upon certain factors of our environment. We have already seen that both plants and animals need the air, water, light, soil, and a favorable temperature in order to live. Even man, with all his ability to change and control his environment, cannot go beyond the narrow boundary of the sea and air that surrounds our earth's surface Even if, like the modern aviator, he carries oxygen with him, he is limited to the supply he can take, or if, like Beebe, he penetrates the ocean depths, he is limited by the strength of his bathosphere and the amount of oxygen he can take with him.

Living Things Respond to the Environment. Almost all of us have kept pets and think we know pretty well what

"being alive" is. Our dog or cat exhibits his liveness in running to meet us, in frisking about, in barking or mewing, in eating and sleeping, and in any one of the various things that a live dog or kitten will do.

We can say what living things will do and predict pretty well what they will do under certain conditions. We know our dog will come to us when we call him, will growl or bite when annoyed, will eat when hungry, and drink when thirsty. He will retreat to his kennel to get out of the sun and will whine to get in the house when he is cold. And if we compare a boy or girl with a dog, we find them very much alike in the way they act under similar conditions. These conditions which, in the case of the dog, the boy, or the girl, affect the organs of sight, hearing, taste, touch, or some other sense, are called *stimuli* and they all are said to react to stimuli of its environment. Living things react to stimuli and things that are not alive do not.

SELF-TESTING EXERCISE

Select from the following list those words that best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

divisors	dividing	food	characteristic
factors	substance	creations	animals
plants	living	kind	environment
life	drink	subtracting	parts
same	responsive	dead	different
stimuli	inside	turn	multiplying
middle	outside	respond	similar
cells	other	grow	adding

Living things differ from nonliving things in several definite ways. Living things always come from (1)____ similar (2)____. Reproduction is a (3)____ of both (4)____ and (5)____. Then living things (6)____, not from the (7)____ like a crystal, but from the (8)____. Living things are always made up of tiny

units of (9)____ material called (10)____. These have (11)____ sizes and shapes, according to the (12)____ of structures they form. But they are always very tiny and grow by (13)____ into more (14)____ like themselves. Living things use (15)____ for this purpose. Then things that are alive (16)____ to (17)____ from outside themselves. They are thus said to be (18)____. They are also dependent upon the (19)____ of their (20)____ and if any of these are changed, it may mean the death of the living things there.

STORY TEST

Mary Writes on Being Alive

Read carefully and critically. List all the errors and suggest corrections.

I know that I am alive. How do I differ from something that has no life? Well, that isn't hard to say. I can jump about and play and move and a dead thing can do none of these things. However, I haven't told what being alive is.

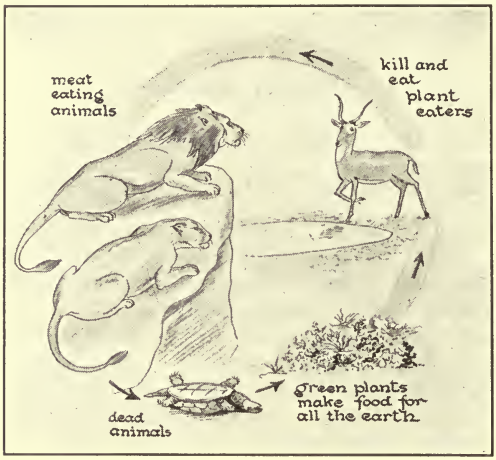
People used to think that living things came from dead things, like flies from dead horses or snakes from horsehairs. Some people still believe such things. But Louis Pasteur, the French scientist, proved they were wrong hundreds of years ago.

A living thing always thinks. A living thing has a special shape, both legs and arms. It hears, it moves, and it has weight. Oh, yes, and a living thing grows and uses food for this purpose. But I do not know what life is any more than do the scientists.

PROBLEM II. HOW DO GREEN PLANTS SOLVE THEIR LIFE PROBLEMS?

Green Plants Make the Food of the World. There have been sun worshipers among men since earliest times. But there has never been a more ardent sun worshiper than a green plant. And there has never been an engine that has done more or better work than the mills that are found within the green leaves of plants. These mills get their power from the sun and can run only in the sunlight. It is a wonderful story — that of how the green plant does its work. And it is all the more wonderful because without this work you and I could not

live. If you think for a moment, you will see why this statement is true. Try to think of some animal that lives on flesh alone — such as a lion or tiger. But it preys on cattle, deer, antelope, and other grass-eating animals. Or take a big trout that lives upon smaller



The food cycle. Follow it through and try to prove that green plants make the food of the world.

fishes, insects, and insect larvae. In every case the food of the smaller animals can be traced to the green plants. Everywhere in nature we find that green plants form the basis of the world's food. The great flour mills merely change the raw food materials made by the wheat plant into a form that we prefer to eat. Other animals like cattle eat the food as the plant makes it. See if you can find any cases of animals that do not depend on plants for their food, and bring the case up before the class for discussion.

How Are Plants Fitted to Do Their Work? Everyone is familiar with a green plant. We all know it has roots which hold it in the ground, an upright stem which bears the green leaves, and sometimes flowers which form fruits

containing seeds. We remember that the two big problems of living things are food getting and continuing their kind. Let us see if we have any clews as to how a plant may do these things. We will take the production of young plants first, because it is easier to see and understand.

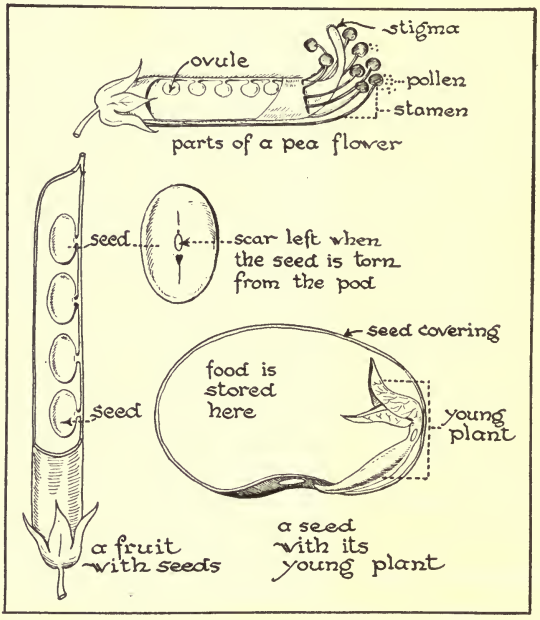
An entire plant. How many structures can you name? Can you give the use of each structure?

The Use of the Seed. If you split open a soaked bean seed and remove the tough coat, you will find a tiny plant between the two "halves" or cotyledons. Such a baby plant is called an *embryo* and is found in all kinds of seeds. Evidently seeds provide plants with a means of reproducing their kind. The young plant which grows is called a seedling. If you plant bean seeds in sawdust, you will be able to see just how the embryo within the seed develops into a plant.

What the Roots Do. Plants always have roots. These anchor the plant, but they do more than that. Later, when we study biology, we shall find that they are provided with millions of tiny absorbing organs which receive water from the ground and pass it into the inside of the root. Here it passes into woody tubes, which run

from the root up into the stem and on into the leaves themselves.

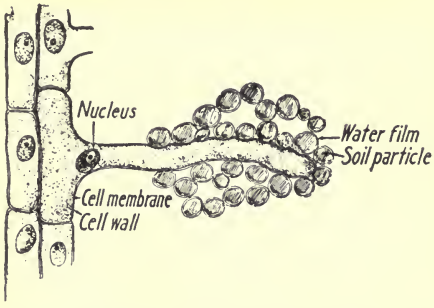
How the Leaves Are Placed. Since the main work of a green plant is food getting and since it has to make its



Can you explain where and how seeds are formed after studying this diagram carefully?

own food out of substances in its environment, we shall want to see how this is done. We have already said that the sun gives the power to run this food factory. And when we are told that it is the green substance inside the leaf that does the work of manufacturing food, we shall naturally look for adaptations in the plant which result in getting just as much sunlight as possible on the green leaves. Look carefully at almost any tree and you will find that not only are most of the leaves placed so that their flat green surfaces get as much direct sunlight as possible,

but you will also find the leaves are so placed that if you could look down in them, they would form a continuous pavement of flat leaves, each crowded in between its neighbor and each getting all the light possible.



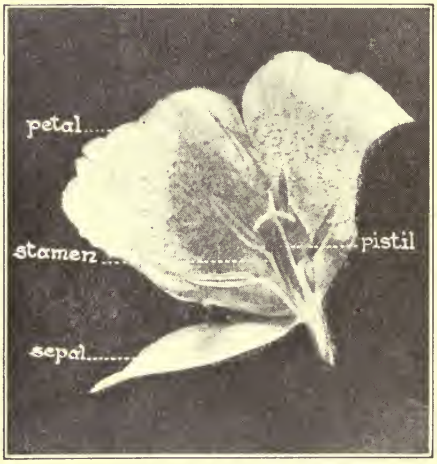
The prolongation is called a root hair. Each rootlet is provided with thousands of these tiny absorbing organs.

Green Leaves Make Food. Green plants almost always have leaves. These flat green structures are of various shapes and the soft green tissues are supported by veins. The veins are really bundles of tiny woody tubes which carry water up from the roots to the leaves and food down from the leaves to other parts of the plant. The surface of the leaf, usually its under surface, is filled with tiny breathing holes called *stomata.* The leaf is a complicated food factory in which the power to do work is provided by the sun, the raw materials supplied from the air through the stomata and from the roots by the veins. The work is done in the green part of the leaf. Carbon dioxide from the air and soil water from the roots are combined into food in the green parts of the plant, while

Study this diagram carefully and then tell how the leaf gets the raw materials to make food.

Wright Pierce

Will all of these flowers produce fruit? Read your text carefully before you give a reason for your answer.



This is a simple flower of the lily family. Its parts are in 3's. Do you find any evidence of this?

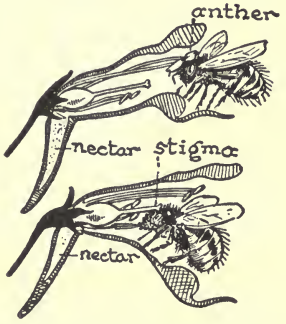
oxygen is given off as a waste product during the process. We shall learn more of the details of this process in our later study of plants and animals.

How Plants Grow. Green plants grow larger and produce more leaves and branches because the buds, which you can find in the winter on the sides and tips of the branches, burst open and grow either into branches with their leaves, or into flowers. You have all seen an apple, apricot, or other fruit tree in bloom. The flowers come in the spring so that there is plenty of time for the seeds to ripen before cold weather. The food and water necessary for growth is transported through the tubes in the leaves and stems to the places where rapid growth is taking place.

Thus we may have very rapid growth of some parts.

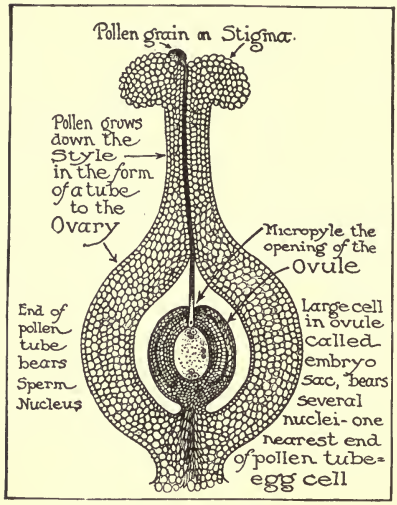
Of What Use Are Flowers? If you will study the picture of the flower on the opposite page, you will find certain structures called *stamens.* They contain pollen grains of which we will learn more later. In the center of the flower we see another structure called the *pistil.* The enlarged base of the pistil, called the ovary, holds the structures which will later become seeds. If you cut open an ovary, you will find the future seeds, called ovules, fastened to the inner walls of the ovary.

What Results from Pollination. If you have ever visited a garden, you could not help but notice bees visiting flowers. If you watch one carefully to see what it is after, it will be seen to poke its long tongue down into the flower. It is after nectar, the sweet secretion out of which bees make honey. But bees also gather pollen, the yellow tiny grains which are made in the tiny boxlike anther of the stamens. So it often happens that the bees, in their quest for food, transfer pollen from the stamen of one flower to the pistil of another flower of the same kind. This process is called cross-pollination and results in the growth of the pollen grains which light on the end of the pistil. These grains grow a long tube downward into the lower part of the pistil, called the ovary. This tube carries with it several cells, one of which, a very tiny body, is called the *sperm* cell, which unites with a larger *egg* cell hidden in the ovary. This process is called *fertilization* and results in the growth of the fertilized egg into an embryo or baby plant. Only seeds with live embryos will grow into young plants. It is thus seen



Explain how a bee might carry pollen from one of these flowers to another.

that fertilization of the egg is about the most important thing that can happen, so far as the future of the plant is concerned, because it makes possible the growth of a new plant after the parent plant is dead. You may have noticed in shelling peas that some pods have only a few full sized peas in them, the places where the other peas should have grown containing only little green knobs. These are the ovules that did not get the eggs in them fertilized.



This is a section cut vertically through a flower and magnified under the compound microscope.

How Plants Scatter Their Seeds. One other thing must happen if a plant is to be successful. It must be able to scatter its seeds. Plants, like weeds, which produce many seeds and which have good devices for getting them placed far from the parent plant are the most successful ones. In the case of some of the fruits which are good to eat, birds, animals, or even man may eat the fruit and pass out the undigested seeds with the wastes, thus giving the seeds a start in life. In some parts of the country birds have planted rows of trees along fences where they roosted after eating and it is no uncommon thing for squirrels to plant pine or other trees as they carry off the seeds to store for the winter.

SELF-TESTING EXERCISE

From the following list select those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

stars	minerals	water	seeds
reproduce	sound	food	air
world	right	blue	baby
food factory	holes	seed	roots
flowers	round	green	right
sunlight	embryo	moon	oblong
make	sun	left	angular
flat	stem	yellow	red

Like other living things plants have two big problems for existence. They must get (1)____ and (2)____ their kind. But green plants do not get (3)____; they (4)____ it. And they make not only their own (5)____, but also supply the (6)____ with it. To do this they must have (7)____ coloring matter in their leaves and must have a good supply of (8)____ for the (9)____ supplies the energy to run the (10)____. In order to get much (11)____ surface exposed to the (12)____ we find leaves are (13)____ and placed so that usually this surface is at (14)____ angles to the sun's rays. The leaf uses raw materials to make food, part of it, (15)____, coming up from the soil by way of the (16)____ and (17)____ while another part, carbon dioxide, gets into the leaf from the (18)____ through its breathing (19)____.

Plants solve the problem of continuing their kind by forming (20)____. These are formed in the (21)____. Each (22)____ contains a tiny (23)____ or (24)____ plant which under favorable conditions will grow into a new plant.

STORY TEST

Harry Tells How Seeds Are Formed in Plants

Read carefully and critically. List all the errors and suggest corrections.

Most plants have flowers, although some of them are so small you don't notice them. These flowers form fruits which contain seeds, some just one or two and others a lot. The queer thing is that seeds have in them baby plants and if you plant a seed it always forms a new plant, no matter where it is placed. But only one seed from a fruit will grow, all the others must die.

These baby plants get into the seeds in a queer way. Flowers have two kinds of things growing in them, surrounded by the colored petals and green sepals. These are the stamens, little knobby things which hold pollen and another thing in the very center called the pistil. This holds the ovaries that later will become eggs. When pollen gets on a pistil it grows a tube and then part of the tube unites with the pistil and we have an embryo.

Martin Johnson

What kinds of foods do each of these animals eat?

PROBLEM III. HOW DO ANIMALS PERFORM THE BUSINESS OF LIFE?

What are the chief problems of animals? Unlike the green plants they cannot make food, but must get it. This, then, is the big problem of living. To be successful animals must know where and how to get food. Have you ever tried to find out the different ways in which animals you have seen get food? Grazing animals like sheep or cows cut the grass for their fodder and then chew it over and over again. They do not seem to have very hard work to get their food. But how different it is with a bird or a fish. Have you ever watched big trout or bass feed? They sometimes jump clear out of the water after insects or they may make a rush at a school of minnows and snatch one or two before they can get away. They are hunters and have to be very active if they are not to go hungry. A bird, like a robin, must be quick when it sees an insect or an earthworm. A flash of the bill and the insect or worm is gone. Watch the big yellow and black spider as it lies in wait in its circular web. When a fly or other insect touches the web, the spider is awake in an instant and soon throws out sticky threads of silk that hold the victim fast until the spider can paralyze it with its poison fangs and then suck its body juices at

leisure. These few examples only serve to illustrate the hundreds of ways in which animals are fitted to catch and eat their food. The grass or plant eaters are called *herbivorous* animals, while the flesh eaters are called *carnivorous.*

How Animals Are Adapted for Getting Food. If you were to go to a museum, it would not be hard to answer this question. You could see the lions and tigers, with their sharp claws and teeth fitted for holding and tearing their prey once it was caught, or an elephant, with its curious long nose or proboscis, by means of which it seizes its food or perhaps sucks up water for a drink or a bath, or a snake coiled up ready to strike might fascinate you. Birds with beaks and feet fitted for various kinds of hunting or fishing might next be seen or we might find a case showing how insects of various sorts get their food. There are many strange ways that marine animals get their food which we have not even mentioned — stinging tentacles by which some jellyfish or sea anemones paralyze their prey, currents of water set up by clams or oysters by means of which tiny plants and animals are carried to the mouth of the creature, claws or pincers of lobsters or crabs which seize the prey, or even in the case of the simplest of animals the whole body wraps itself around the food and takes it in. Wherever we go in the animal world, the most important adaptations are those which give the animal its chance to secure food and eat it.

Animals Are Like Machines. As we shall see later, the food which is taken by the animal is used to enable it to do work and to grow. Food, like coal in an engine, is burned in the body to release the energy it contains. So the business of living consists in changing the food after it is procured into a form in which it can be used. This we call digestion. Other activities are necessary: The digested food must be carried to the parts of the body where it can be

Martin Johnson

N. Y. Zoölogical Society

In each of the four animals give all the adaptations you can for food getting, protection, and locomotion.

used; wastes must be passed off; and finally the food must either be built into the body to make new living stuff, or else oxidized to release energy. We shall hear more of this in a later unit.

Animals Must Reproduce Their Kind. If animals are to be successful, they must leave some of their kind behind them to carry on after they are dead. Eggs must be produced, and when the young emerge, they must be protected until they can take care of themselves. Protection of young is necessary if animals are to be successful in life. Birds often lay only one or two eggs as against millions of eggs laid by certain fish. But because the

bird protects and feeds its young, chances for growth to adult life of an equal number are as good, if not better, than in the case of the fish which leaves the young to look after themselves. In the mammals, animals which suckle their young, such as the cow, dog, cat, or man, the mother not only carries the young in the body until it is ready to be born, but also cares for it during babyhood — thus making its chances of growing to adult life much better. In our own case we are cared for, not only during our life as a baby, but also for a long time afterward. Animals which are most successful in life are those which have best solved the big problem of food-getting, protection from their enemies, and rearing of young.

SELF-TESTING EXERCISE

Select from the following list those words which best fill in the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

swallow	getting	cutting
food	teeth	tearing
eggs	nests	protection
care	beak	claws
piercing	catch	suckled
grinding	holding	people
heads	continuing	adaptations
kind	homes	releasing

The two great problems of animals are the (1)____ of (2)____ and that of (3)____ their (4)____ on the earth. Food (5)____ largely depends upon the (6)____ that the animal has which enables it to (7)____ and (8)____ its food. The (9)____ tell just what kind of food an animal eats. An herbivorous animal will have teeth for (10)____ and (11)____ while a carnivorous animal has teeth for (12)____ the prey and then (13)____ it with teeth and claws. You can tell from the (14)____ or (15)____ of a bird the kind of food it eats. Adaptations for the (16)____ and (17)____ of the young are numerous. Some build (18)____, some animals hide their (19)____ in places where they will be hatched by the warmth of the sun, while in animals when the young are born alive they are (20)____ by the mother.

STORY TEST

JOHN SHOWS HOW FIDO IS FITTED TO OBTAIN FOOD

Read carefully and critically. List all the errors and suggest corrections.

Fido is my cocker spaniel. I do not think he is very well fitted to get food, for his legs are short and he is not very fast or quick in getting about. But I know he makes up in wisdom what he lacks in agility. His teeth are all sharp and all pointed and some are curved so he can hold fast to his meat. He likes meat best of all, but he will drink milk. He laps the milk with his long tongue. I have taught him to beg and to speak for food and I think these are adaptations for he gets food by means of them. His feet are rather flat and padded and his claws do not stick out much, another adaptation so that he can steal up on his prey.

PROBLEM IV. WHAT LIVING THINGS ARE FOUND IN MY YARD OR GARDEN?

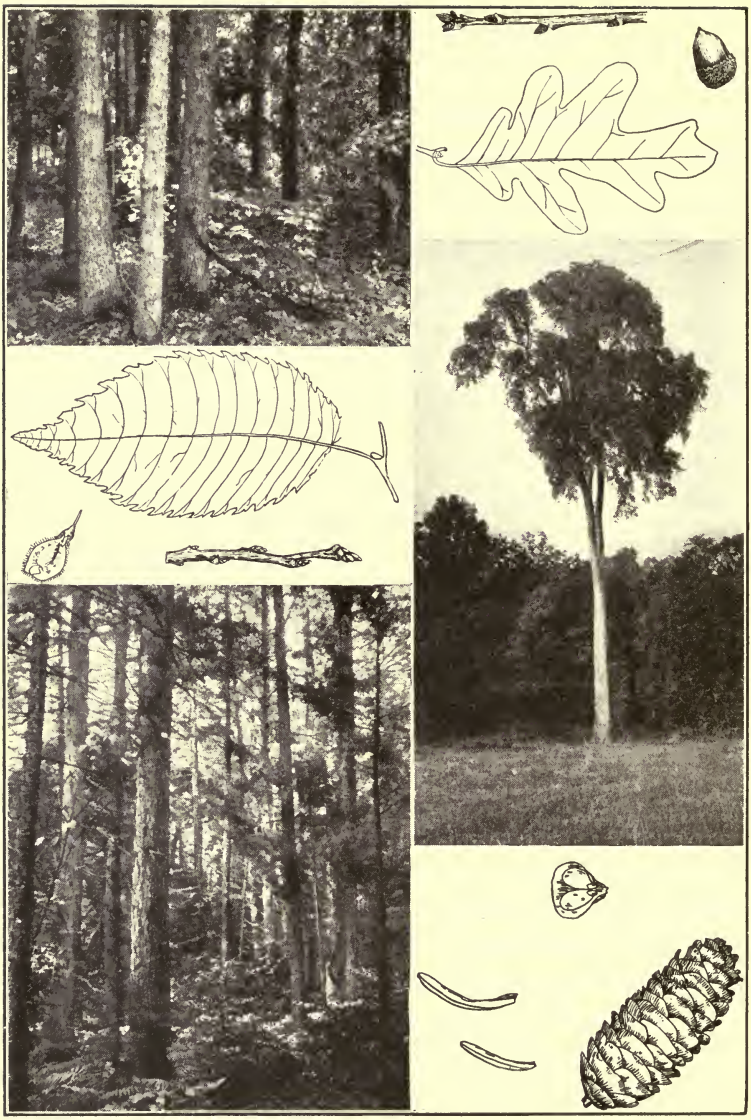
What a Survey Would Show. If you were to make a survey of a part of the school grounds or your own home surroundings, you would notice that plants and animals could be placed in two groups, those that are native to the place and those that have been introduced from some other places. Some weeds, grass, many trees, earthworms, most birds, toads, and insects would come under the first heading, while many other trees, most of our shrubs and flowers, and our garden vegetables would come under the head of introduced plants.

Common Shade Trees Differ in Various Parts of the Country. Most shade trees lose their leaves in winter and so are called *deciduous* (from the Latin meaning to fade away). In New England the elm, maple, birch, and oaks are the most common shade trees; in the central West other varieties of maple and oak would be found along with the poplars, beeches, hickories, sweet gum, and ash. When we get beyond the Mississippi Valley the cottonwoods, poplars, and sycamores become more prominent,

while in southern California we rarely find native trees in the yard, for most of them have been introduced from other localities. In addition, many kinds of ornamental shrubs or bushes may be found. These plants are usually quite low and have several stems instead of one long trunk like a tree.

Evergreens. Most yards contain evergreens which are often introduced because of their beauty. The term "evergreen" means that such trees do not shed their leaves all at once as do our deciduous trees. The evergreens, such as spruces or balsam firs, may usually be told by their small needle-like leaves. The pines have straight, tall stems and the needles come out in groups of from two to five in a cluster. The hemlocks and balsams have needles which come out singly but are arranged on opposite sides of the twig, while the needles of the spruce come out singly but all over the branch, like bristles on a brush. The evergreens produce their seeds in cones and so are called *conifers.*

Deciduous Trees. It would be impossible to give more than a few hints as to how to know the common deciduous trees. You must go to one of the reference books for that. But some different trees can be told from their leaves and bark. For example, the maples have their branches opposite on the trunk and leaves sharply pointed and deeply notched. Maple fruits are winged seeds held together in pairs. The birches and poplars have easily distinguished outer bark, which is yellow green on the poplar and light colored and easily peeling in the birches. The elms are known by their graceful shape and leaves, shown on the next page. The oaks we recognize by their fruit, the acorn, and their much-lobed leaf. This paragraph will give you a start. Get a good book and see how many trees you can identify. There may be a few trees and a good many shrubs and cultivated flowers that you cannot



The upper picture shows an oak forest with its leaves and fruit; the middle picture shows an elm with leaves and fruit; the lower, conifers with fruit. Which of these are deciduous trees? How many deciduous trees do you know?

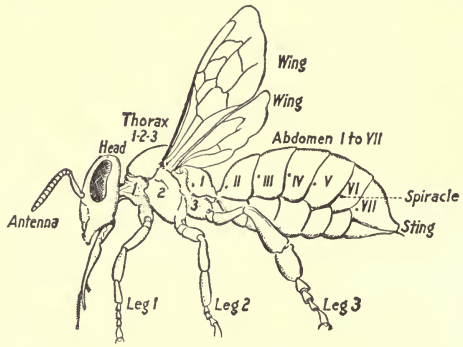
find in your book of reference. Go to a garden catalogue for them.

Animals in the Home Grounds. You will say at first that there are no animals in your home grounds, unless it be your pets, dogs, cats, or birds. Occasionally you will have a rabbit that feeds upon your lettuce, and in the far West the gophers and ground squirrels may become

How many animals can you find in this picture? How many can you add that are found in your home grounds?

pests. But if you have trees and shrubs, there are almost certainly birds to be found nesting. You are quite sure to find a toad or two living in the garden. A good many more insects than are desirable are also likely to be found feeding on the plants or shrubs. Snails and slugs feed on your flowering plants, while earthworms, ants, and several kinds of insect larvae may be found in the earth. Let us see what we can learn about some of these friends and enemies of our trees and gardens.

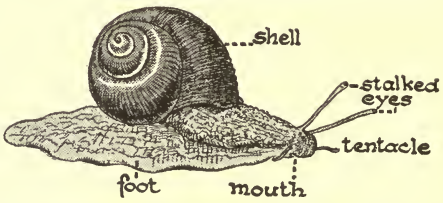
Animals Which Harm Our Gardens. There are many kinds of insects, mostly in the young stages, which destroy our plants. Adult insects can easily be distinguished because they have three divisions of the body and three pairs of legs, but the young stages, or larvae, harmful grubs, or caterpillars, are not so easy to recognize as insects because they have false legs.



Study this diagram carefully and then compare it with some animal you think is an insect. Tell how you would identify an insect.

The insects most likely to be found in the home yard are crickets and grasshoppers, insects with chewing mouth parts and strong hind legs used for jumping; winged butterflies and moths, the latter usually flying at night, both distinguished by the fact that the wings are covered with dust-like scales; hungry caterpillars which are the young stages of moths and butterflies; beetles, heavy set insects with hard wing covers, bees, wasps, and ants; and the destructive bugs, the latter distinguished by their snout-like beaks, through which they suck the juices of plants.

Another group of animals that do harm are snails and slugs. These animals belong to the same group as clams, oysters, and mussels. They are called *mollusks* (Latin *mollis* — soft) because they have soft bodies. Most mollusks have shells, but others, like the slug, do not have one. Some snails



Snails are very destructive in gardens. The mouth, on the underside, is not shown.

move by means of a muscular foot, which can be seen in action if the snail is allowed to crawl on a glass plate. The mouth, with its sharp teeth, can be seen on the underside of the foot. You can also see the head with its tentacles and stalked eyes when the snail is moving about.

Friendly Animals. — Fortunately there are some friendly animals that live in the garden. One of the best friends is the toad. Toads are not often found in the bright sunshine, but at dusk or on rainy days they may be found squatted under the leaves of some plant, on the lookout for insects. Watch one and see if you can find out how he catches them. His slimy tongue is the weapon and his use of it is very accurate. Toads are vertebrates because they have backbones. They belong to the group called *amphibia* (Latin *amphi* — both), so called because they pass their lives both on land and in water. We should always protect the toads, for they eat cutworms and other garden pests. Occasionally harmless snakes are found which live upon the rodents like field mice, gophers, or rabbits. So we see even in our garden there is a continual struggle for existence.

Toads are useful neighbors. Did you ever see one catch an insect?

Some Animals Found on or in the Ground. There are several different kinds of animals that live under boards or stones or in the ground. Pull up a board that has lain on the ground for some time and you will be surprised to

How many animals can you find and name?

see the numbers of tiny animals there. Ants go hurrying away, a spider or two may be found, and perhaps the round cocoon or egg case containing a number of baby spiders. Other near relatives of the insects are the "thousand leggers" or millipeds, worm-like creatures with many legs. The pill bugs are wood lice that roll up into a ball, from which they get their name. The sow bugs are also wood lice, but cannot roll themselves into a ball. These are closely allied to the lobster and crayfish. They have jointed bodies and jointed legs and belong to the group called *crustaceans*.

The earthworm often makes part of the burrow under boards and will withdraw quickly if disturbed. Earthworm burrows are interesting to follow, and if care is taken in digging, you will sooner or later find its owner. Earthworms differ from the crustaceans in not having jointed legs, although the body is segmented or jointed.

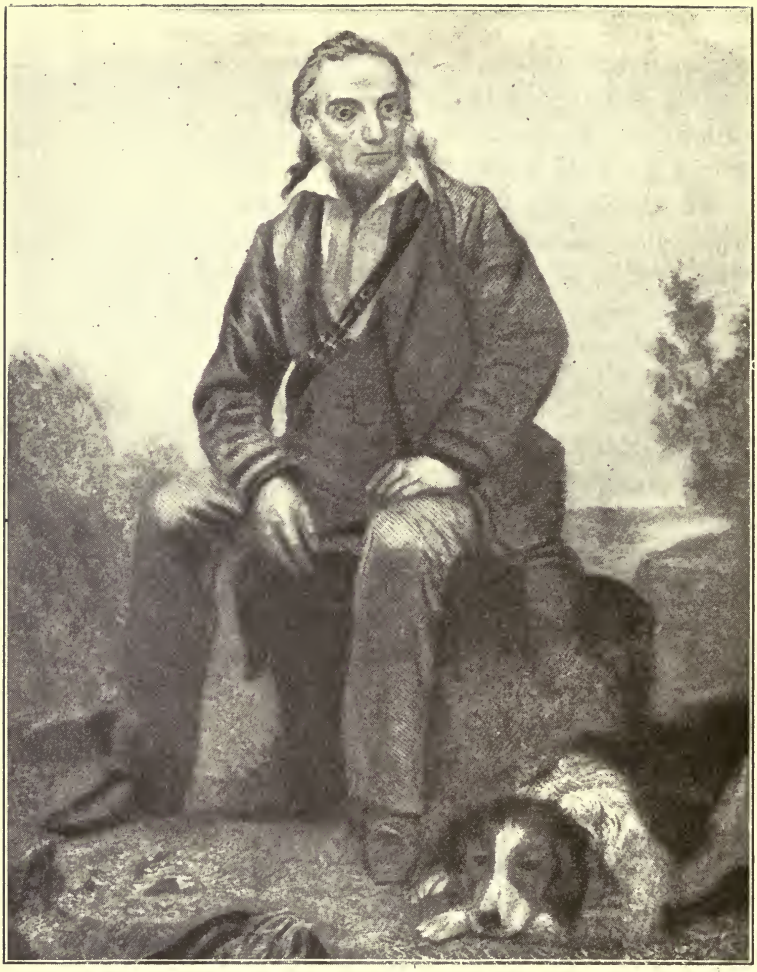
Although earthworms have no eyes, ears, or feelers, they are very sensitive to light, touch, and odors. If you do not believe this, try some experiments with living worms and see for yourself.

Why Birds Are Important Neighbors. Have you ever tried to take a census of the birds in your locality? You must first know which birds are *residents*, or stay all year, and those which are *migrants* and go somewhere else part of the year. The latter usually come in the spring and stay with us for a time.

Nests and Their Uses. Nests are indications of the habits of the birds that build them and are interesting as pieces of adaptive work. Some are simply loose masses of sticks made like a platform on which the eggs are laid. Such nests are made by crows, hawks, and the brown thrasher. The birds which live near homes usually make nests that are carefully lined with down, grass, or other fibrous materials to make them more comfortable. Most birds do not use their nests a second year, so a collection of nests for the school museum can be made without harm to their makers if taken in the late summer or fall.

Wright Pierce

What can you tell about the habits of the birds that made these nests?



JOHN JAMES AUDUBON, 1780–1851.

AUDUBON was a born naturalist, a keen observer, and a remarkable artist. Although he inherited wealth, he soon lost all his money and for many years wandered through the Ohio and Mississippi valleys almost penniless. But during this time he was making a wonderful collection of paintings of birds, which afterwards became the illustrations for his famous *Birds of America.*

Some Birds Found in Home Grounds. Most of the birds frequently found on the home grounds are perchers, having four toes in front and one behind, making a foot well adapted to perching. In this large group are found the thrushes, which include our robin; the wrens, little birds with a cheery note and sociable disposition; the mocking bird and its relative, the catbird; the sparrows, all useful weed-seed eaters except the English sparrow;

Wright Pierce

Wright Pierce

What can you tell of the habits of these two birds from their photographs?

the blackbirds, meadow larks and grackles, and many others. The woodpeckers and flickers, with two toes pointing forward and two backward, make up another order, while the hawks and owls, birds of prey, are placed in a group which has claws and beaks adapted for tearing.

How May We Attract Birds? There are several ways in which birds may be attracted. First, nesting boxes may be made. The birds which frequent such houses are the wrens, blackbirds, martins, woodpeckers, and, unfortunately, English sparrows. Houses for wrens can be placed near the house, for they are friendly little creatures. Be sure to make the entrances too small to admit

the English sparrows. Bluebird and martin houses can go into the garden either on a post or nailed to a tree. The martin house should have several entrances because if the bird house has only one entrance, the English sparrows may get possession and the martins cannot drive them out. The woodpecker box should be deep, with cleats attached below the hole so that the bird will have a place to light on.

Wright Pierce

A bird bath that is safe. Cats cannot disturb birds here.

Bird baths and feeding places are other means of attracting birds. The drinking fountain and baths must be so placed that cats will not be able to disturb the birds. Feeding boxes or shelves, on which are placed cracked corn, bread crumbs, chopped meat, and in winter a piece of suet, will attract birds if feeding is done at regular times.

SELF-TESTING EXERCISE

Select from the following list those words which best fill in the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

high	shrubs	low
green	fins	legs
wings	dead	soft
fangs	millipeds	migrants
residents	hardy	toads
mollusks	protect	water
protect	earthworms	destroy
pollen	spiders	insects
flowers	crabs	amphibians
conifers	bushy	deciduous

Many different kinds of living things may be found in one's yard. Two kinds of trees are (1)____ or evergreens, and (2)____ trees, which shed their leaves in cold weather. Then we find (3)____, small tree-like plants having a (4)____ appearance. Many forms of animals are found, (5)____, which feed on garden plants, or take nectar or (6)____ from the flowers; (7)____, which live on the ground and feed on the insects; (8)____, which live in the soil and many other small animals. Toads and frogs are called (9)____, because they pass part of their lives in the (10)____. Snails and slugs, which live on plants, are called (11)____ because they have (12)____ bodies, while the thousand leggers are (13)____, so called because of their many (14)____. Most important of all are the birds which (15)____ the trees and plants from destructive (16)____ and cheer us with their pleasant songs. Birds are either all-year-round (17)____ or (18)____.

STORY TEST

MARGARET TELLS WHY WE SHOULD PROTECT THE BIRDS

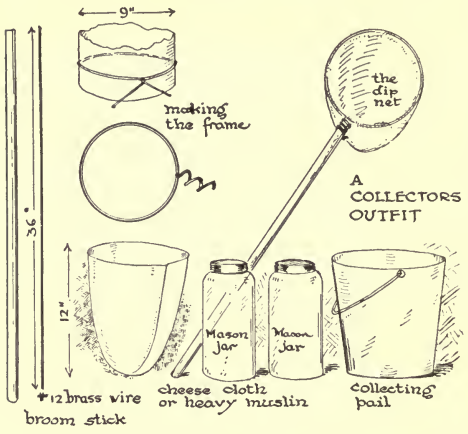
Read carefully and critically. List all the errors and suggest corrections.

Birds are good neighbors, because they are pretty and have sweet songs. I like the robin's note in the spring. In cold weather I guess he stays in his nest, for I never see him. Most birds like the robin or oriole stay in the north all the year, but a few, like the woodpeckers migrate south to escape the cold weather. Sparrows (except the English sparrow) are especially useful, for they eat harmful insects. We can attract birds by feeding them, by making bird baths, and by attracting the English sparrows and starlings, which the other birds like.

PROBLEM V. LIFE IN STREAM AND POND

How to Prepare for a Collecting Trip. Have you ever gone on a collecting trip to a stream or pond? If you have, you know what fun it is and how many interesting creatures live in this habitat. You will need a pail, a few Mason jars with covers, and a long-handled net. This you can make out of a broom handle, a piece of steel wire for the frame, which can be bent and fastened into the handle as is shown in the illustration. The net can

be made of coarse cheesecloth or mosquito netting. With this equipment you can capture all sorts of animals for your home or school aquarium.



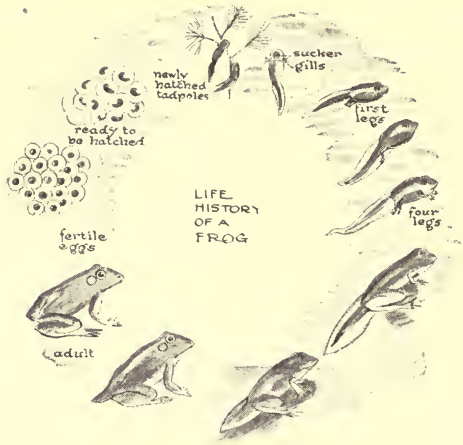
It would be an interesting project to make a net like the one shown above. Why not try it?

Zones of Life. As we observe life in a stream or pond we soon see what living things frequent one of several zones; they may be in or along the bank, in the water, on the water, or in the air just over it, in or under stones in the brook or pond. Each zone has its own collection of inhabitants. For example, the young stages or larvae of some insects, worms, and little crustaceans, to be known by their jointed bodies divided into two parts and jointed legs, will be found in the mud or crawling on the bottom or under stones. Fish, crustaceans, and insect larvae are in the water. Insects will be in the air or on the surface film of the water, while larger animals like turtles and frogs, although they may be in any of these zones, will be likely to be found sunning themselves on the bank. Water plants are much more restricted to their own particular zone. The many forms of algae, plants with thread-like bodies or with finely divided leaves living in the water, pond lilies with floating leaves at the surface, and many water weeds frequent the banks, offering shelter to insects and other small animals. In every case, if you look, you can find many adaptations for aquatic life. The stems are thin and long, for the plant

is supported by the water it lives in. Leaves are either numerous and much divided, as in plants under water, or the leaves are brought to the surface by long thin stems, which are supported by the water. This enables the leaves to get sunlight. List as many other adaptations as you can in your workbook.

How Fish Live. You will usually find small minnows in a brook, which can sometimes be caught in your net. The chub or dace, minnows, and sticklebacks are often found in brooks, while the perch and sunfish are quite often found in small ponds. If you watch a fish carefully, you will see that it frequently opens its mouth, as if it were biting. It is doing this in order to take in water which passes out over the gills or breathing organs. You have all seen the gills, red feathery structures on each side of the head, covered by the cheek bones. These gills are able to take oxygen out of the water. Look for clear round areas of gravel. These are nests of the sunfish, and if you can see one of the fish there, it is quite likely to be a male guarding the nest. The eggs are laid in these nests, and sometimes a lucky stroke of the net will bring in some, which you can watch develop in the school aquarium or in a small saucer at home.

Frogs and Turtles. Several different frogs may be seen. The big bullfrog can often be caught with a bit of red flannel on a hook. They are too large for your aquarium. A better frog to keep is the spotted leopard frog or the green frog. Notice how well fitted they are for aquatic life. The slimy, streamlined body, the big webbed feet, the eyes so placed that they can see without being seen when they are at rest on the surface of the water. If your trip is taken early in the spring, look for the eggs of frogs and toads. The former are laid in masses of jelly, usually attached to some sunken sticks or weeds near the surface of the water. Toads' eggs are laid in strings of



Study the diagram carefully and then make an estimate of the time that elapses between each of the stages shown above.

jelly in shallow water. Be sure to bring in some eggs if you find them so you can watch their development.

You may also see several different kinds of turtles. They make interesting pets, but should not be kept in the aquarium, for they will eat the other inhabitants. If you watch a water turtle, you will notice that he comes to the surface after a time, and that quite often under water he gives off a stream of bubbles from his mouth. This shows that he breathes by lungs, and has to come out frequently for air. The spotted mud turtle is found in brooks, while the painted turtle is found in shallow ponds. A snapping turtle is occasionally found. Be careful if you pick him up, for he has a long neck and sharp jaws. Soft-shelled turtles are common in the South and in the far West.

The western painted turtle, commonly called water turtle.

Other Inhabitants. Most brooks and ponds are inhabited by snails. Several different kinds will be found living on water plants or crawling on stones or along the bottom. They make an

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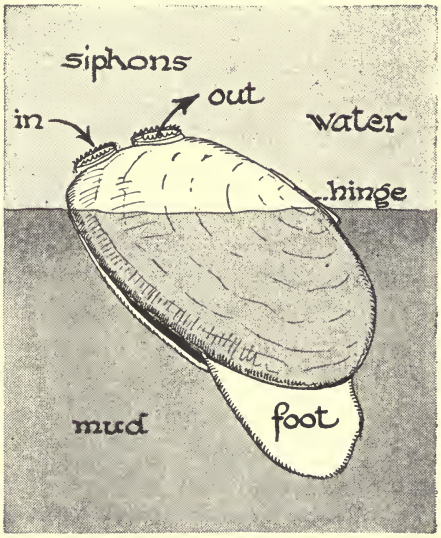
Turtles make good pets. You can keep them in a pen in your yard. Sink a small tub in the ground and give them plenty of shade in hot weather.

excellent addition to the aquarium and will often lay their eggs on the glass walls, where they can be watched in their development with a hand magnifier. Fresh-water mussels and tiny clams are often found. Both of these live nicely in aquariums. Bring in as many different kinds as you can and try to identify them with the aid of some of the books mentioned at the end of the unit.

Crustaceans which have jointed bodies and jointed legs are also likely to be found. The largest crustacean we are likely to see is the crayfish, which will often be found in shallow, slow-running brooks. It makes its home in tunnels in the banks of the stream. It has a jointed body covered with a hard skeleton, with five pairs of walking legs, the front ones armed with pincers, two pairs of feelers, and eyes mounted on movable stalks, like the lobster.



Fresh water mussels are called clams by most people. Notice the siphon, through which the animal gets its food and oxygen, and the muscular foot, by means of which it moves.

The female carries her eggs on the under side of the jointed abdomen. Crayfish must be kept by themselves, for they, like the turtle, will eat the living things in your aquarium.

The crayfish — (*A*) antennae or feelers; (*M*) the line points to the mouth; (*Ch*) the chelipeds or big pincers; (*E*) the eyes on stalks; (*CF*) the caudal fin or tail; (*CP*) the cephalothorax or head and body part, and (*Ab*) the jointed abdomen. How many pairs of legs has the crayfish? How many joints in the abdomen?

Many other crustaceans will be found: rarely, small shrimps, and more frequently, flattened "sow bugs," "water fleas," and copepods. Many smaller crustaceans, almost too small to see with the unaided eye, swarm in the ponds, forming food for fish and in turn feeding on still smaller animals and plants.

Many Insects Live in the Water. Many insects are attracted to water, as they lay their eggs in it and the young live either in the mud or water. The larvae of the dragon fly, called nymphs, are mud-colored, strong-legged creatures, which carry a pair of hinged jaws on the front of their heads, which they shoot out to catch their prey. They may often be found on the bottom of a quiet stream and can be brought to the school laboratory. Keep them in a separate jar, for they prey on other living things. Another carnivorous insect is the beetle known as the water boatman. It will even attack small fish. Many other insect larvae live in the mud, such as the young of the water boatman, stone fly, damsel fly, and others. Mosquito larvae or wigglers are often found, either quiet at the surface or wriggling through the water, and the

larvae of many different flies live in tubes fastened to stones. You can learn to identify these in any good book of aquatic insects. Some insects live on the surface film of the water, while others, as the water boatman and water bug, swim near the surface. Look in Downing's "Our Living World," if you want to learn more about these interesting forms.

The life cycle of the dragon fly. How does the larva catch its foods? What happens before the adult is hatched out?

SELF-TESTING EXERCISE

Select from the following list the words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once if necessary.

fishes	lizards	larvae	embryos
adults	mollusks	divided	slimy
stems	adaptations	jellyfish	turtles
frogs	webbed	toads	gills
held down	long	crustaceans	algae
buoyed up	flowers	lobsters	seaweed

Things which live in the water show (1)____ for this kind of life. Plants have finely (2)____ leaves and (3)____ thin (4)____, because they are (5)____ by the water. Aquatic animals are likely to have (6)____, fins, (7)____ feet, or (8)____ body. In brooks we are likely to find (9)____ such as minnows or chub, (10)____, which lay their eggs in masses of jelly; (11)____, which have to come to the surface to breathe, (12)____, as snails, mussels, or clams; (13)____ which have jointed legs and bodies covered with a hard skeleton, and many insects, both (14)____ and (15)____.

STORY TEST

JOHN TELLS ABOUT HIS COLLECTING TRIP

Read carefully and critically. List all the errors and suggest corrections.

Our teacher wanted some living things for our school aquarium, so I went after some. I chose a stream I knew near home. It was sluggish and filled with sewage, but I thought this would be a good place to find living things, particularly fish. But here I was disappointed. There was plenty of dead stuff for food, but no fish except a few polliwogs. I did find some mosquitoes and their larvae, little wrigglers, that went zigzagging through the water as if they were drunk. I also found lots of snails and a few crabs. Most of the water plants I hoped to find were not there, but I did find plenty of water cress which I brought home to eat. I think it grows plentifully there because there was lots of filth for it to grow on. It will be safe to eat after it is washed.

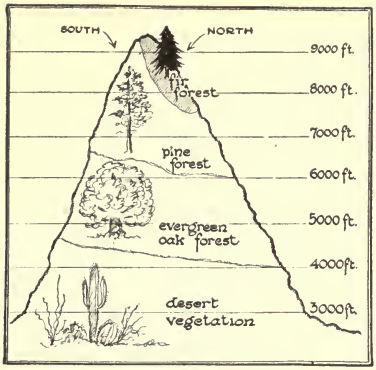
PROBLEM VI. LIFE IN THE FOREST AND ON THE MOUNTAINS

Forests a Refuge for Wild Life. Some boys and girls fortunate enough to live in the country know what it means to take a hike in a real forest. Others may have gone to the mountains on a holiday and remember the forest-covered mountain sides, with their deep valleys and canyons through which a clear stream came leaping down. Here the fisherman might find sport in the pools and any nature lover could see wild life at its best — squirrels in the trees, a mink swimming in the brook, trout jumping for flies, and birds enjoying themselves on the pebbly bank. The forests and mountains are the last stand of the original life that inhabited this country before civilized man changed it. The government has wisely enough thrown large areas of our mountains and forests into great national parks and forests, which will always give the citizens of our nation a place to play as well as make a refuge for the few of our original wild animals.

Wright Pierce

The "Elfin forest" or chaparral. Notice the zone of larger trees higher up on the slopes of the mountain. How do these western mountains differ from those in the East (see page **234**)?

Zones of Life in the Mountains. Any one familiar with the mountains of southern California knows that they rise up out of the desert and that the lower slopes are covered with chaparral, the "Elfin forest," made up almost entirely of tough shrubby growth that can exist without much water. This growth is of great use, because it helps to hold in the soil the small amount of rain that falls there. Further up these mountains we come to another zone of life, big pine trees appear, and at an altitude of from 6000 to 8000 feet we have forests. Still higher the trees become more sparse and stunted until at about 10,000 feet we come to a zone of dwarfed growth almost like that of northern Canada. Taking the train inland from Veracruz to Mexico City, we can pick wild bananas at the coast and wild strawberries the same day



The diagram on the left shows the life zones on a mountain rising from the desert in Arizona. See if you can find any of these zones in the picture at the right.

at 6000 feet elevation; while at 11,000 feet you could have a snow fight. This change in vegetation is caused largely by differences in temperature.

On a mountain side in the eastern United States the forests are much denser and clothe the mountains from base to peak. Only at an altitude of over 5000 feet do the trees begin to get smaller. At the summit of Mt. Washington in the White Mountains or Mt. Marcy in the Adirondacks we do find alpine conditions with bare rocks and a few stunted trees in sheltered places.

Forests Differ in Different Places. The forests of the western mountains are largely yellow pines, with scattered conifers and a few aspens or other deciduous trees. In the East, however, we have largely mixed forests: hemlocks, spruces intermingled with ash, beech, hickory, birch, maple, walnut, and many other hardwoods. In the southern states the conifers are mostly cypress and pine, while catalpa, magnolia, locusts, and sweet gums are added to the list of forest trees given above. Some forests in the areas where rain is abundant are carpeted with fern and other undergrowth, while in the dryer West the trees are not crowded so closely together and forests

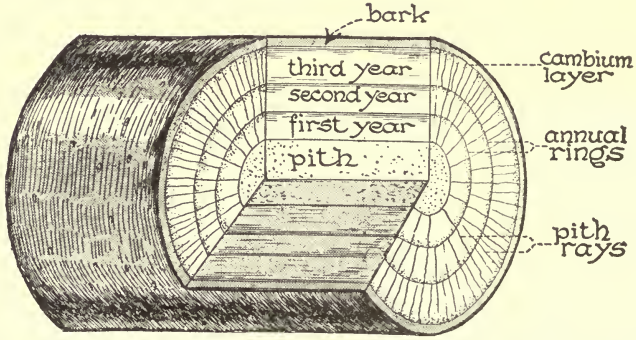
contain park-like areas scattered here and there, covered with grass and flowers, making an ideal place for deer and other grazing animals.

Forests Support Many Living Things. Forests serve not only as homes for our native birds, but also for many other wild animals. The woodpeckers, warblers, thrushes, creepers, and many other insect-feeding birds are found there, as well as some of our game birds such as quail and grouse. Forests are also the home of the few wild animals that are left, such as deer, antelope, elk, bear, wildcat, or coyotes. Along the streams live some of the larger gnawers, such as beavers and muskrats, while hosts of squirrels and smaller rodents live in the trees or in the ground. Insects in great numbers feed upon the leaves of forest

Wright Pierce

A forest of yellow pine in the Far West. Notice how far apart the trees grow. Would you find this condition in Maine? In Michigan? Explain.

trees. Many insect larvae, as the forest tent caterpillar, the caterpillars of the gypsy moth, the tussock moth, and the brown-tail moth eat the leaves of forest trees. Beetles bore in the wood or eat the roots, and scores of other insects do their best to destroy our forests. Fortunately the birds which live there feed on the insects and keep the destruction down. So we may say the future of our forests rests largely with our birds. If we kill the birds, we also may kill our trees. In addition, man often does harm by setting fires which destroy hundreds of thousands of trees, or sheep are allowed to browse in forests and destroy young seedling trees.



This tree grows both inward and outward from the cambium layer. How much did it grow last year? How old is the tree? How can you tell this?

How Do Trees Grow? If you break off a rapidly growing shoot from a forest tree, you will find it much softer than an older branch. A cut trunk shows a series of well-marked rings of growth. The branch or tree trunk grows from an area just under the bark. This soft area, known as the *cambium*, is a place where the cells of the tree are rapidly multiplying in warm weather. They grow in both directions, inward to form wood and outward to form bark. Each winter growth slows up, and in spring it becomes more rapid. This irregularity in growth causes the rings of growth seen in trees. It is thus true that each

ring represents a year of growth, and we can tell the approximate age of a tree by its yearly rings of growth.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

areas	dwarf	bush	plains
conifers	pupae	deserts	birds
few	zones	no	wild
trees	destroy	large	tame
upper	mixed	chaparral	large
lower	maggots	grasses	larvae

Plant life on a mountainside is in (1)____. At high elevations there are (2)____ trees, a little down there are a few (3)____ trees, while still lower the forests are made up of (4)____ trees. In the Far West, where the mountains rise out of the (5)____, their (6)____ slopes are covered with (7)____ like (8)____. In the West the forests are largely made up of (9)____, but in the East and South the forests are (10)____ growth. Forests are the last place left where (11)____ animals can live and they also protect our native (12)____. Many insects, particularly their (13)____, live upon forest (14)____ and would (15)____ them were it not for the (16)____ which in turn feed upon them.

STORY TEST

Sallie Tells about a Trip to the Forest

Read carefully and critically. List all the errors and suggest corrections.

The forest I visited was not far from our house. It was largely made up of spruce and pine trees and as the trees are scattered every which way it is called a mixed forest. There is a brook which flows through the woods and I have counted as many as six or seven little fish — I think they were trout, in one pool. These fish have a large head and a small tail, and sometimes they seem to have little legs growing from their bodies. I also saw a good many frogs there and some jelly-like masses with little black dots inside, which I took to be fish eggs. In the trees I heard a good many birds and I saw one redheaded woodpecker making holes in the bark of a tree. I think he was after food, perhaps sap. I noticed

one tree had a lot of holes in which acorns were lodged. I couldn't see how they got there, for the tree was a pine and there were no rats near. Who can tell me what caused this to happen?

PROBLEM VII. LIFE ON THE SEASHORE

How to Equip Yourself for a Collecting Trip. If you live near enough to the coast to take a collecting trip to the seashore, you will be repaid by seeing examples of life that are not found in fresh water. For such a trip you should have a large pail, a few pint jars or wide-mouth bottles with corks for holding specimens, a small spade, an old knife or a small iron bar for prying off animals fastened to the rocks, a small pair of tweezers, and, if possible, a hand lens or reading glass.

Life Zones. Evidently the salts in the water control the life in the environment, for the forms most found have no near relations inland where these salts are lacking. We find the environment along the shore is marked off into zones of life; first, an upper zone of dry sand and rocks drenched by salt spray during storms; next, an

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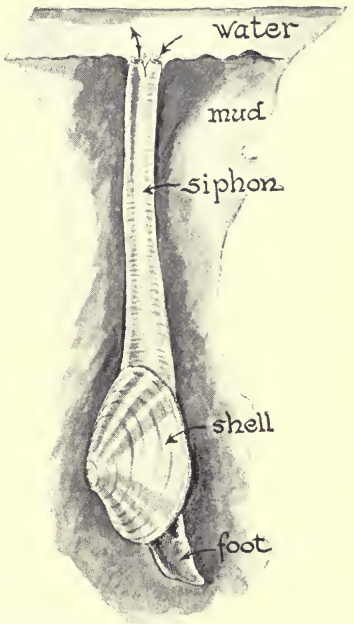
Can you find the life zones mentioned in your text in this picture?

inter-tidal zone, either seaweed-covered rocks or sandy beaches and flats; and then a third shallow-water zone found just off shore.

Life on the Shore. The upper zone, stretching from high tide to the grass and trees of the soil, has little life. There are sea birds, animals like rats or rabbits which wander in from the fields, a few insects, principally gray grasshoppers that harmonize beautifully with the sand, and great hordes of little sand hoppers or sand fleas, tiny crustaceans, which constitute most of the life. These last named animals are abundant, especially in the windrows of seaweed thrown up at the high-tide line.



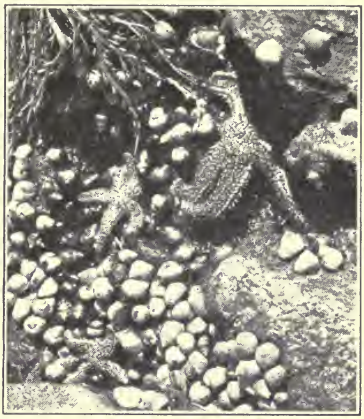
A salt-water "long" or "soft" clam. Compare this mollusk with the one shown on page 285. What difference do you find? Would this tell you anything about the changes in habitat?

The Intertidal Zone. The intertidal zones may be sandy beach, sand and mud flats, or rocky coast. Each of these environments houses quite different animals and plants. The sweep of the tide and the pounding of the waves make life in this area hard. As the tide comes in, it brings food in the shape of tiny one-celled plants and animals (collectively called *plankton*), and many animals such as small fish, crabs, starfish, and snails come in to feed. As the tide goes out, the flats become crowded with scavengers, gulls and other birds, crabs and other crustaceans. Even land animals, such as beetles, crows, and rats, may come down to feed. The sandy beaches and

flats are the permanent homes of many mollusks, little periwinkles, and other snails almost covering the surface in places. Other larger snails, whelks, are found, as well as many bivalve or two-shelled mollusks. Some of these, like the scallops, not permanent residents, live on the surface of the sand or mud; others, like mussels and oysters, are attached to the rocks; while still others, like the clams, burrow into the sand by means of a muscular foot. Some clams have long tube-like siphons which project out to the surface. Through the siphon the animal gets oxygen and water containing microscopic food. (See page 295.) Many little green or brown crabs will be found, as well as the funny little hermit crabs carrying around snail shells in which they have made their homes.

Life in the Sand or Mud. The sand or mud is honeycombed with burrows of several different kinds of worms. One of the most common is the sandworm, which has a jointed body, each joint provided with flat appendages strengthened with many bristles and a head provided with horny jaws, tentacles, and four eyes. Other segmented (jointed) worms may be found, as well as some unsegmented species. Small crustaceans and burrowing crabs are often seen digging into the sand at our approach, while sea cucumbers and sea urchins, both "spiny skinned" animals, are sometimes found on the surface of the sand.

Life on the Rocks. Along a rocky shore quite a different association of animals is found. Here we will find great densely-packed communities of barnacles, a fixed crustacean, easily distinguished by its white shell divided into plates; while mussels of several species are numerous, half covered by masses of brown fucus or other seaweeds. Often we find starfish or sea urchins, while sheltered under rocks and in pools are the wonderful sea anemones. These animals belong to the same group as the corals. When



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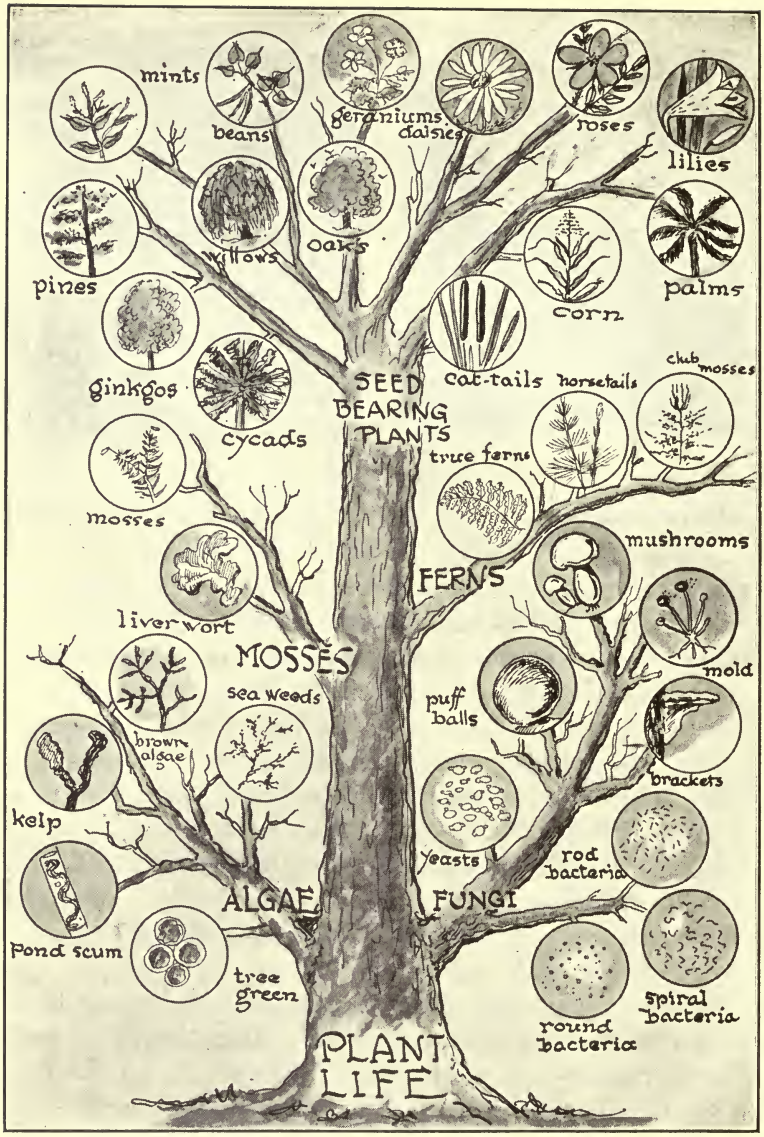
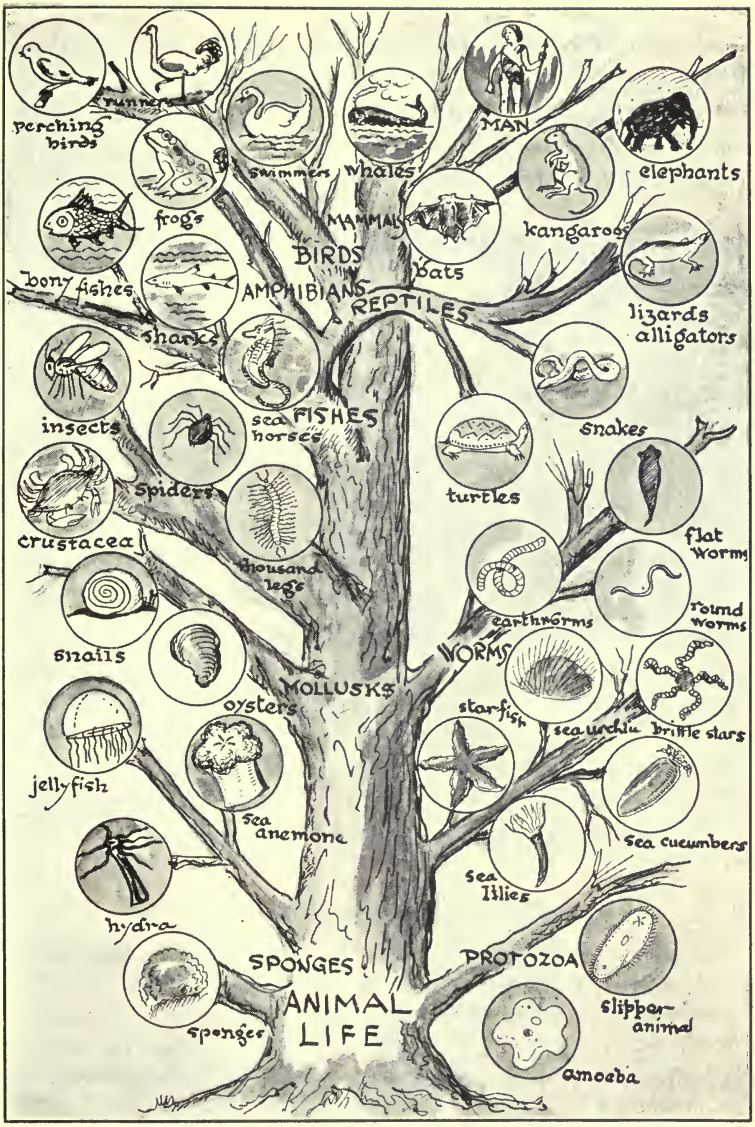
Would you expect to find any living things in the area shown in the left-hand picture? If so, what plants and animals? Where would they be found? Where would you expect to find the animals shown in the right-hand picture? To what groups of animals and plants do they belong?

they are extended, they look like great red, brown, or yellow chrysanthemums. When touched, they close up, pull in their colored tentacles, and look like a lump of dull-colored mud. Tidal pools are rich finds, and one can watch the living creatures there by the hour, discovering new forms of life at every turn. Small fish, several species of crabs and other crustaceans, tube-building worms, dense masses of tiny animals that are close relations to the sea anemone as well as numerous varieties of starfish and sea urchins are likely to inhabit most tidal pools. Why not make a list of all the forms found in a single pool as a project or report?

Along a rocky shore many interesting new forms will be found by turning over flat stones. Here beautiful leaf-like flatworms are often found. These can be put into a jar of salt water, where they will swim with a slow undulating motion. Beautifully colored naked mollusks with projecting gills are sometimes found. Of course, the rocks are covered with delicate red, brown, and yellow seaweeds.

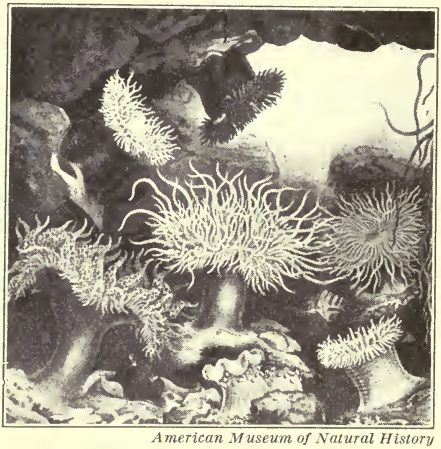


How many of the forms of plant life shown here have you ever seen? Make a list for your workbook, telling where you saw each form you mention.



How many of the forms of animal life shown here have you seen? Make a similar list to that mentioned on the opposite page.

Life in Shallow Water. In the shallow water and on the bottom near the coast are found hosts of other plants and animals. Kelps, eel grass, and other sea plants float and wave in the water, making an ideal hiding place for small fishes, crabs, lobsters, starfish, and numerous other small animals. Many starfish and sea urchins, as well as barnacles, snails, mussels, and other mollusks, may be found. A most interesting project would be to make a list according to zonal distribution of all the forms of life you can find on a trip to the shore. Remember such a trip is best taken on the outgoing tide, and to be really successful you should have a very low tide. Dress warmly, but with old clothes, for you will get dirty and wet. Have with you, if possible, a good illustrated book on sea life.



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Life in a tidal pool. How do you account for the differences in appearance of the sea anemones?

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

mosses	jump	burrow
birds	scallops	crustaceans
anemones	dead	robins
segmented	insects	algae
frogs	flat	owls
snails	fish	mollusks
life	polliwogs	cucumbers

Life along the seacoast is divided into zones. The upper zone above high tide has little (1)____, a few (2)____, (3)____, and sea (4)____. The zone between high and low tide is teeming with life. On the rocks are found many (5)____, mussels being the most plentiful, while different kinds of slow moving (6)____ are also found there. Clams (7)____ in the sand while other mollusks like (8)____ or (9)____ live on its surface. Many worms, both (10)____ and smooth, also live in the sand. Sea (11)____ are in the tidal pools, along with small (12)____, many (13)____, seaweeds, and mollusks. Under stones we find (14)____ worms and on the rocks many forms of red, brown, or yellow (15)____.

STORY TEST

Dick Tells about His Trip to the Shore

Read carefully and critically. List all the errors and suggest corrections.

Several of our class organized a trip to the shore last week. We consulted the tide tables and found high tide was in the afternoon, so we went then. We went to Rocky Point and found the water calm so we could get out on the rocks. They were mostly under water and covered with seaweeds, so we couldn't find many living animals. I fished for a while and got some small fish and a big crab. I saw some gray grasshoppers on the rocks and lots of gulls appeared to be catching them. I also saw millions, I guess, of little sandhoppers just above the high-water mark on the rocks. But on the whole I should say there were not many kinds of living things on the beach or rocks. This doesn't agree with our book; I wonder why.

THE REVIEW SUMMARY

This unit will be a little difficult for you to make a summary on because much of the material has to do with ways in which you can identify the plants and animals in certain localities. But there are some big ideas or generalizations which we can make. See if you can add any to the list that follows:

1. Living things respond to stimuli and adjust themselves to their surroundings.
2. Living things can change food into living matter.

3. Living things are made up of cells.
4. Living things come from other living things.
5. The kind of living things found in a given place depends upon the environment.
6. Certain plants are always associated with certain animals in a given environment.
7. Green plants manufacture food for animals.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of the statements you believe to be incorrect. Your grade = right answers* $\times$ 2.

I. **Living things:** (1) differ in different environments; (2) have adaptations which enable them to live under certain definite conditions; (3) are able to make some adjustments to changes in conditions; (4) cannot ever adjust themselves to changed conditions; (5) are not affected by their environment.

II. **Living things differ from lifeless things because:** (6) they respond to stimuli; (7) they grow; (8) they feel; (9) they are made of cells; (10) they arise spontaneously.

III. **Green plants:** (11) depend upon animals for their food; (12) use water as their only food; (13) use water and carbon dioxide to make food; (14) need sunlight if they are to make food; (15) need not be green in order to make food.

IV. **The following adaptations for food making can be found in green plants:** (16) the stem is long and straight, proving a good passageway for foods; (17) the leaves are usually placed so that they get the most sunlight possible; (18) in many plants stems turn toward the light; (19) leaves are flat and the most green material is placed on the side from which the sunlight comes; (20) the flowers only produce seed in the sunlight.

V. **Animals show adaptations for food getting:** (21) when their eyes are placed far at the front of the head; (22) when they are inconspicuous; (23) when their claws and teeth are sharp and

pointed; (24) when they have teeth fitted for grinding; (25) when they feed on the young of other species.

VI. **Birds:** (26) like the English sparrow do much good by eating seeds; (27) like the woodpecker, do much harm by making holes in trees, thus causing them to die; (28) protect our forests by eating harmful caterpillars; (29) are adapted to their life by having a large heart, light hollow bones, feathers, and front legs modified to form wings; (30) which are native to the home grounds are pigeons, plover, and crows.

VII. **In a stream or pond:** (31) we may observe zones of life, each having its own plants and animals; (32) the fish lay their eggs in the mud; (33) insect larvae live on the bottom; (34) turtles have to come out to breathe; (35) frogs lay their eggs in masses of jelly.

VIII. **In the mountains:** (36) we would always expect to find the largest trees at the bases; (37) of the southwest the big trees are found at over 6000 feet elevation; (38) the change in kind of vegetation is largely due to differences in temperature; (39) you would expect to find buffalo and reindeer; (40) many native insect-killing birds make their home.

IX. **You would never expect to find:** (41) sea anemones in salt water; (42) living starfish in the upper beach zone; (43) worms on the rocks along the seacoast; (44) crustaceans in the sand of the beaches; (45) sea urchins on the rocks.

X. **A lynx is:** (46) a crustacean; (47) a vertebrate; (48) a mammal; (49) a cat; (50) none of these.

THOUGHT QUESTIONS

1. How many ways can you find by which a fish is fitted for its life?
2. Why is it that sometimes the school aquarium does not keep its "balance" of life?
3. How would you prove that without birds we could not have gardens?
4. How could you tell the difference between an herbivorous and a carnivorous animal?

REPORTS UPON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.

2. Ways in which a living thing depends upon its environment.
3. The chemical factory in a green leaf.
4. Just what are the important differences between a plant and an animal.
5. Living things I have found interesting on my field trips.

SCIENCE RECREATIONS

1. Take a hike to some place where you think you can collect living things and make a map of the locality showing where different plants or animals can be found.
2. Take a trip to a near-by park and see how many animals you can find feeding. Make a list for your notebook and tell just what they eat, how they get their food, and how they eat it.
3. Take a trip to a "zoo," select ten different animals, and make a list of all their adaptations.
4. Make a collection of pictures showing adaptations to environment.
5. Make a survey of the birds nesting in your vicinity and locate their nests.
6. Make a tree survey of your block and make recommendations for tree planting.
7. Select a small area in your yard and study it carefully over a period of one week. List all the living things you find, both plants and animals. Find out, if possible, the names of the various plants. Make two lists — native and introduced. Look for birds. List all you recognize. Make descriptions of those you do not know and try to identify them from some bird book. Look under the leaves, in stems and bark, on the ground, and in the soil for insects. Look in and on the soil, especially under boards and stones, for other animals. You will be surprised to see what a long list you have by the end of the week.
8. Make a bird calendar in which observations of migrants will be kept.

SCIENCE CLUB ACTIVITIES

1. To make a collection of plants inhabiting some particular environment, mount them and make labels telling all the adaptations you can find in each.
2. Prepare a skeleton of a dog or a bird, mount it, and label all the adaptations for life you can find.
3. Make an excursion to the shore and bring back materials to stock a salt-water aquarium.

4. Arrange and label the school museum, making it an up-to-date collection of animals that live in your environment.

5. Collect and cut sections of small branches from different forest trees in your locality. The sections can be smoothed, varnished, and mounted with leaves and fruits of the tree, thus making a valuable addition to the school museum.

6. *How to Make a Balanced Aquarium.* An aquarium can be made by having a tinsmith make a frame of angle tin into which you can cement glass sides and ends cut to fit. A good size is about 8″ by 12″ for the bottom, the sides 6″ by 12 ′, and the ends 6″ by 8″. A waterproof aquarium cement can be purchased and the glass cemented into place. It should be left to harden for several days before it is used.

Stocking the Aquarium. The pond or stream you visit will certainly have several species of water plants or algae. Green plants that live under water are necessary in order that they provide food and oxygen for the animals that live in the aquarium. Bladder-wort, milfoil, water moss, or some of the slimy pond scum will make useful plants. Snails will act as scavengers and will eat the tiny green algae that may form on the sides of the aquarium. Add stones and sand for the bottom so as to give your insect larvae a place to live and plants to root. Remember crayfish, dragon-fly larvae, and especially the larvae of the giant water bug will eat all living things, so do not try to keep them. Use brook or pond water and be sure *not* to add city water that has been chlorinated or you may destroy the lives of your pets. Keep records and make observations on the doings of the various inhabitants and you will be surprised how much of interest you will find out about the lives of these tiny neighbors whose presence many people do not even suspect.

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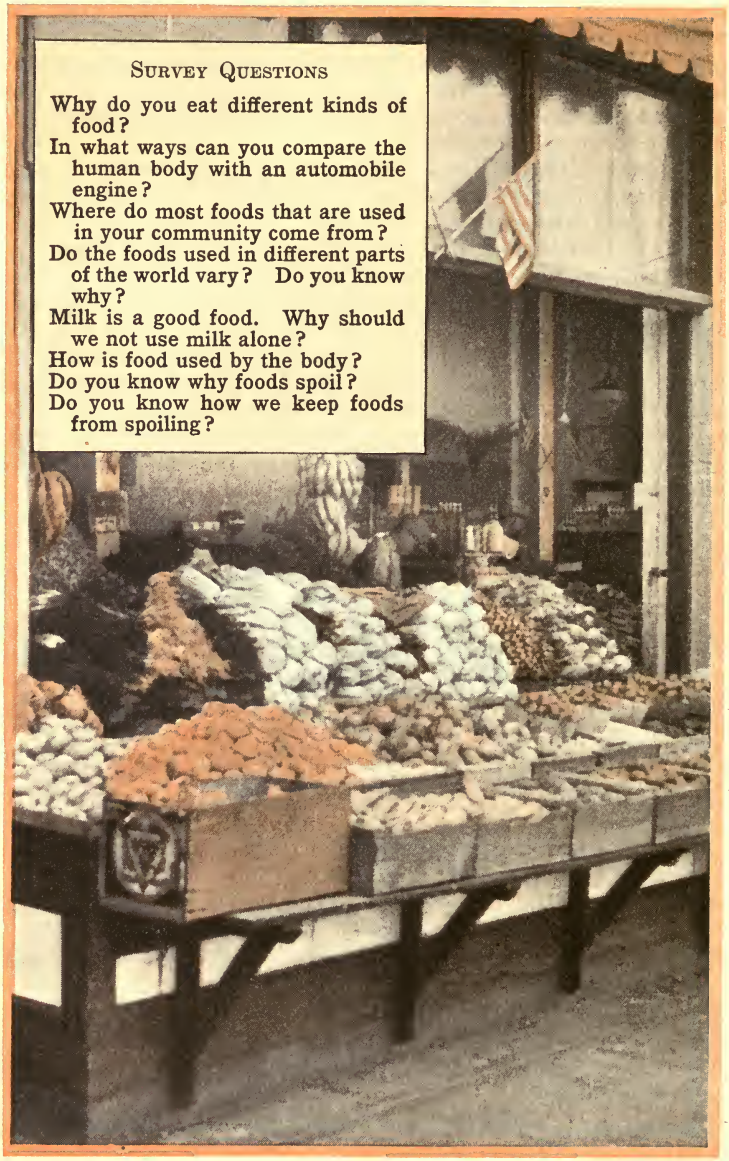


Survey Questions

Why do you eat different kinds of food?

In what ways can you compare the human body with an automobile engine?

Where do most foods that are used in your community come from?

Do the foods used in different parts of the world vary? Do you know why?

Milk is a good food. Why should we not use milk alone?

How is food used by the body?

Do you know why foods spoil?

Do you know how we keep foods from spoiling?

Burton Holmes for Galloway

UNIT XI

THE FOODS WE EAT

PREVIEW

If you could take a trip around the world, you would be much amused to see what different kinds of foods different people eat. In Japan we would find fish and rice most used as food; in China, rice or millet, fish, and some strange foods, such as edible birds' nests and shark fins; in the Philippines the natives would be found eating the fish they catch and the native fruits and vegetables found there in abundance; in India, corn often takes the place of rice and we have milk and butter used as well as many vegetables and fruits that we know and like. The story would be different for each country, for each would have its own peculiar foods, but all people use food for the same purpose that we do.

What is true of man is equally true of plants and other animals. A plant as well as an animal may starve to death. Ask any farmer about this. Does this mean that a plant actually eats soil, water, and sunlight, or do plants use foods as we do? Green plants do use foods for the same purposes as animals do, but there is a great difference in the way they get their food.

Do the different kinds of foods really make any difference in our growth or the way we feel? We can answer that question by feeding white rats on different foods to see what happens. Rats use the same kinds of food that man does, so the results of feeding rats help to show what the effect would be on man. Recently a series of

interesting experiments were carried out by some school children in Texas. They chose six rats of the same size and weight from the same litter, and tried feeding them on the same ration of corn meal, water, and green food, but two of the rats were given milk in addition while two others had chile, another candy, and another a soft drink added to their diet. The children found that "The rats given milk grew to be larger, had finer hair, brighter eyes, were better natured, and were more active" than those which did not have milk. It is experiments like these that give us some of our information about the kinds of foods that are best for growing boys and girls.

We know that our bodies use food not only to release energy so that we can do work, but also they help the body to grow. Rather recently a third use of foods, that of protecting and regulating the body, has been found. We will later learn something about the kinds of food that do these things.

If foods are oxidized in the body, the amount of energy given off ought to depend on the kind and amount of food that is eaten. This, in a general way, is true. People who do hard physical work should eat more food, and food that has greater fuel value, than those who lead inactive lives. The boy or girl who plays hard needs more fuel food than another boy or girl of the same age and weight who stays indoors reading. People in the arctic region, where the cold makes demands on the system and where hard work has to be done in order to gain a scanty living, consume much more heat-producing food than do people living in the tropics. In our own country we eat more food and more heat-producing foods in the winter than we do in the summer. We have heard of people fasting for long periods of time. In order to do this they dress warmly or go to bed so as to prevent the body heat from escaping. Since they do not exercise, very little energy

is used and, therefore, they can exist for longer periods without food than if they were living an active life.

We know that foods spoil, but we may not always know the reasons for this. We shall learn later that there are tiny plants called bacteria and fungi, which are the cause of this spoiling. They are always present in the air and will grow rapidly whenever the conditions of moisture, temperature, and food are favorable.

How are the human body and an engine alike? Would these boys need the same amount of food if they were studying?

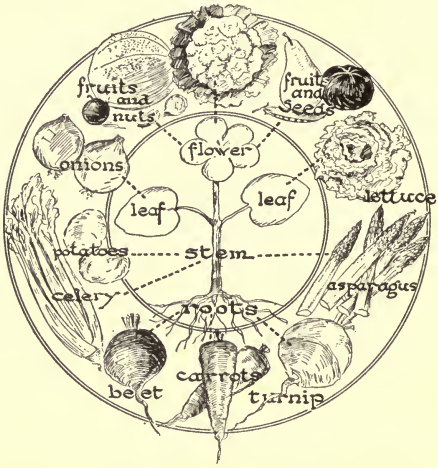
PROBLEM I. WHAT ARE FOODS AND WHERE DO THEY COME FROM?

Where Do Foods Come From? Make a list of all the different kinds of food you have eaten in one day, including water, salt, pepper, etc. List the foods which come from animals or plants, and those that do not come from living things.

If we study this list we notice several things. First, that many more foods come from plants than from animals. Second, that we have a greater variety of plant than of animal food and that we use more parts of plants than of animals. In animals, the part we call meat is really the muscle of the animal. The fat we use sparingly.

In shellfish, such as clams and oysters, we eat practically all of the animal. We use mostly the muscle of scallops, lobsters, or crabs. Milk, cheese, butter, and eggs are animal products.

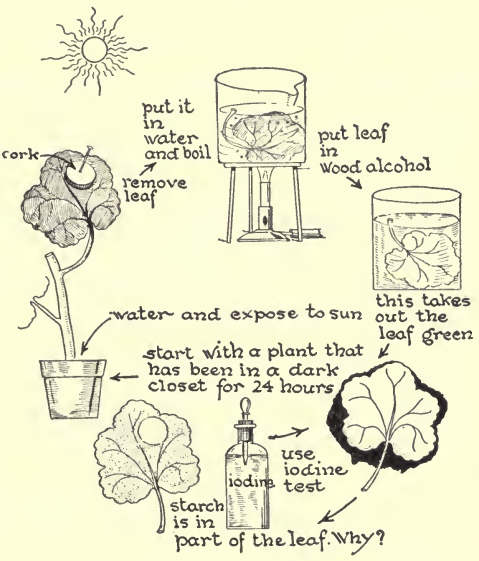
The fruit is probably used more than any other part of a plant. Think of the millions of acres of grains such as wheat, oats, barley, rice, and corn planted in various parts of the earth! Think of the various uses of this seedlike fruit in making bread, cereals, pies, and cakes! Think of the many, many people who live almost wholly on rice or corn, with a little meat or fish! Then there are the apples, pears, plums, grapes, various kinds of berries, and citrus fruits that we all know so well. Millions of dollars' worth of fruits are raised every year in this country. Seeds, such as peas and beans, and nuts form other important sources of food. Perhaps next in importance are roots and underground stems of plants, such as the potato, beet, carrot, and turnip. In some countries stems also furnish important foods. Sugar from the sugar cane, sago from the sago palm, and asparagus are examples of such kinds of food. The leaves of some plants are cooked for greens, such as beet tops or spinach, while others furnish the basis for our salads, as lettuce or romaine. Some vegetables, as onions or artichokes, are formed of



How many more fruits and vegetables can you add to this group? Make lists and place them in your workbook.

thickened leaves. Buds and flowers are occasionally used, cauliflower and Brussels sprouts being the most common examples.

Green Plants Make Food. We have said that green plants make the food of the world. This is very easy to show by means of an experiment. If we take a healthy plant, such as a common geranium, and put it in the dark for at least 24 hours, it will use up all the spare food made in the leaves. While it is still in the dark, we may fasten pieces of cork on some of the leaves. These pieces of cork must be so placed that both sides of the leaf are covered. We will then put the plant in strong sunlight for a few hours. Later we can pick off the leaves which have the cork on them, remove the cork, and boil the leaves. Then we place them in hot methyl alcohol. This takes the green coloring matter out of the leaves and makes them appear to be white. If we now wash the leaves carefully and then put them in an iodine solution,[1] we will find that the area covered by the cork remains white while the rest of the leaf turns dark blue or black. Iodine is a test for the presence of starch.



[1] Made by adding a few crystals of iodine to 95 per cent alcohol, or by adding to one gram of iodine, two thirds of a gram of potassium iodide and then adding enough 35 per cent alcohol to darken to a brown color.

This experiment shows that the part of the leaf which was in the sunlight made starch. Experiments show that starch is always found in leaves that are exposed to sunlight. We can also show that it is not found in leaves that have been left in the dark for some time or in such parts of leaves as have been covered.

Other food materials are also made in the leaf, but the processes are very complicated. After foods are formed in the leaf, they have to be circulated through the body of the plant in order to be used by or stored in the fruit, the seed, the stem, or the root.

What Kinds of Foods Are There? If you were to ask a chemist about foods, he would tell you that they were composed of chemical elements put together in different proportions. Such a classification would give us foods like starches and sugars, which are called *carbohydrates* because they contain carbon, hydrogen, and oxygen; *fats* and *oils*, which are composed of the same elements as the carbohydrates, but in different proportions; *proteins*, which contain nitrogen in addition to the other three elements; water, minerals, and certain regulative substances of a complicated chemical nature called *vitamins*, of which we shall learn more later. If you were to ask the school nurse or a nutritional expert to classify foods, she would tell you that foods may be classified as *fuel foods*, *body-building foods*, and *regulative* or *protective foods*.

SELF-TESTING EXERCISE

Select from the following list those words that best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

protective	green	body	starches
sun's	liquids	yellow	fuel
living	vitamins	inorganic	building
carbohydrates	dead	water	air

organic	sugars	moon's	stars'
destroying	gases	minerals	fats
proteins	germ	soil	fluid

Foods which come from living things are called (1)____ foods, while water and mineral salts are examples of (2)____ foods. (3)____ plants are said to provide food for the world because in the long run the (4)____ energy, acting on the (5)____ coloring matter in leaves, causes (6)____ or (7)____ to be made there from certain raw materials found in (8)____ and (9)____. Foods are classified by the chemist as (10)____, fats and oils, (11)____, water, (12)____, and (13)____. The nutrition expert classifies our foods as (14)____ foods, (15)____ building foods, and (16)____ or regulative foods.

STORY TEST

Julia Finds the Study of Foods Easy

Read carefully and critically. List all the errors and suggest corrections.

I have found this problem on foods and their sources interesting and easy. Many of the facts we know already, for example: Those foods we get from the ground as salt, potatoes, and carrots are mineral foods; those from plants as corn, apples, and wheat are plant foods; and those from animals as eggs, lamb, and beef are animal foods. Milk and vegetables which have an abundance of mineral salt in them are inorganic foods. The fruits, as oranges, bananas, berries, corn, potato, and wheat, are the most-used part of a plant. However, the roots of plants are very important plant foods, among these are the beet, potato, turnip, onion, and peanut.

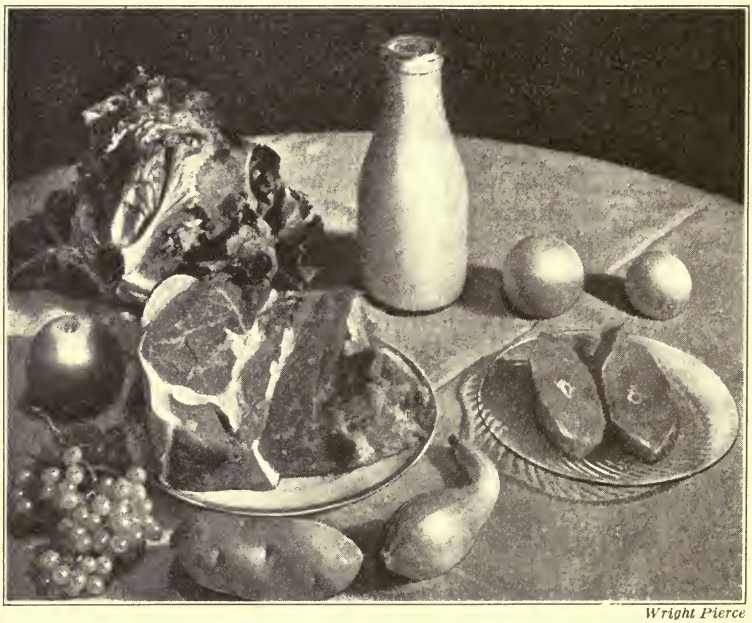
Plants make food out of the raw materials they take up from the earth through the roots. The water from the soil brings carbon dioxide and mineral salts up to the leaves, where sunlight causes chemical changes which result in plant foods. One of these plant foods is sugar, and the test for it is iodine. If food has a drop of iodine solution placed on it and it turns blue, there is sugar in it. The important classes of foods are sugar, fats, proteins, mineral matter, and vitamins.

PROBLEM II. HOW DO WE USE FOODS?

People Live on Foods from Their Own Environment. It is interesting to see that through the ages, long before people knew anything about the chemical composition of

foods, people were strong and did much hard work, although many of them died young. They may not have known why this or that food was good or bad, but we know that they ate different kinds of foods and they ate what was most abundant in their own environments. The Indians lived on fish, fresh venison, or birds with some wild fruits or nuts; the Arab, on dates and figs, grasses, and meat of goats or sheep; the early colonists on such foods as they could bring with them on ships, but soon supplementing these things with fresh meat from the forests and with corn, which they grew in their little clearings.

A Varied Diet Important. Not only did people eat what was easy to get, but they ate a variety of foods. This fact was their salvation. Scientific experiments



Wright Pierce

Do you think you could prepare a well-balanced meal from the food in this picture? Are there any foods shown that you would not change?

tried with large numbers of people show one thing very plainly — that a varied diet is most important. We need foods of all kinds. In order to keep well, work, and grow, we must have protective foods, growth foods, and fuel foods. These foods are usually found plentifully all about us no matter where we live. So for this reason people have been able to get along pretty well in the past, even though they did not know much about the reasons for eating certain foods.

Green Vegetables Important. In the days before refrigeration was known, the late winter found the stock of vegetables getting low and no green food was left. People began to be ill, they were unable to resist disease, and went to the doctor or the drug store for spring bitters or blood purifiers. As spring came on, they began to feel better and attributed their improvement to the medicines. In reality it was the change in diet, brought about by the fact that green vegetables and salads were again available.

Fuel Foods. Your body is like an engine because it does work and uses fuel. Certain kinds of food burn better than others. You can prove this by actually burning a piece of bread, some fat, and a piece of meat

Foods Rich in Starch	Sugars	Foods Rich in Fats and Oils
Cereals	Sugar	Fat meats
Wheat (bread)	Granulated	Salad oils
Corn	Pulverized	Olive oils
Rice	Maple	Lard
Oats	Corn sirup	Peanut butter
Fruits	Beet roots	Eggs (yolks)
Most vegetables	Molasses	Some fish
Macaroni	Honey	Butter
Potatoes	Ripe fruits	Nuts
Cornstarch		Cream

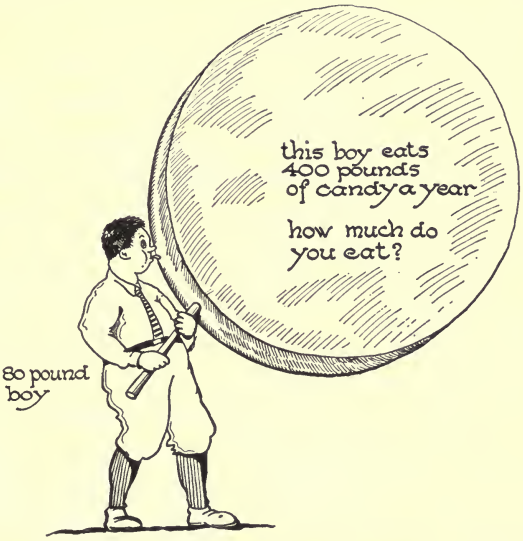
or fish. You know the fat will burn best. Fats release about twice as much heat as do either carbohydrates or proteins. But the carbohydrates do make excellent fuels, and in addition, they are much easier to digest than the fats. So we say that carbohydrates and the fats and oils are the heat- and energy-producing foods.

How about Alcohol? A number of years ago a very famous scientist in this country made a series of experiments to see whether alcohol could be used in the body as a food. He reasoned that because it had the same chemical elements (CHO) as did other carbohydrates, that it ought to be oxidized like other foods. After these experiments he found that some of the alcohol was oxidized and apparently in small amounts it was used as a food. But he also found that it was a very poor food, for it acted like a poison as well. Glycerine, iodine, and many other poisons are oxydized in the body, but they cannot be said to be good foods. As one doctor puts it, the inedible mushroom called the *deadly amanita* contains a poison. It is made up of almost exactly the same amounts of food materials as is found in the edible mushroom, but you would not eat the deadly amanita. Why should you take alcohol if the case is parallel?

How about Candy? Since sugar is a fuel food, we might well ask if candy eating would not be a good way to release energy in the human body. But pure sugar, although it is a good fuel, does not contain any of the mineral and regulative materials found in fruits or cereals. If we would take candy as a dessert along with other fuel foods, it would be useful. But unfortunately candy eating becomes a habit, and not only do we eat it between meals, thus spoiling our appetite, but many boys or girls substitute it for their school lunch, thus depriving the body of better fuels. In one large high school it was estimated that the members of one class were eating enough

candy in a year to equal five times the weight of each boy and girl in that class. If you want to keep that schoolgirl complexion, substitute sweet fruits for candy.

Growth Foods. But the body grows and has to repair itself. Cells multiply in number as we grow in height and weight. They must be made out of something. Chemical analysis of the living stuff out of which the cells are formed shows it to be a very complex substance made up chiefly of carbon, hydrogen, oxygen, and nitrogen, with a much smaller amount of several other elements. The carbohydrates contain the elements carbon, oxygen, and hydrogen, but the proteins contain in addition the element nitrogen. Evidently then, living matter can only be built out of proteins, for the other foods do not contain this necessary element. This is why we call the proteins growth foods. Examples of such foods are lean meat, peas, beans, eggs, cheese, fish, and nuts.



Are you a candy eater? If so, why not figure out how many pounds you eat in a year, and insert the results in your workbook?

The Protective or Regulative Foods. The human machine is not foolproof and will not run efficiently without intelligent care. Most of us eat what we like, without thinking very much of its effect on our bodily comfort.

But sooner or later, if we are careless, we pay the penalty, sometimes in loss of "pep," sometimes in indigestion, or during constipation, or even loss of weight and vitality. The last few years science has made wonderful progress in scientific discoveries about foods, and the most interesting are those about the vitamins, substances which are necessities for bodily growth and health. It has also been proved that certain mineral substances found in milk, water, and other foods are also necessary for health. Such foods are called protective or regulative. It has taken a good deal of experimentation, both with animals and man, to learn all we have about these wonderful substances, and we are finding out more every day.

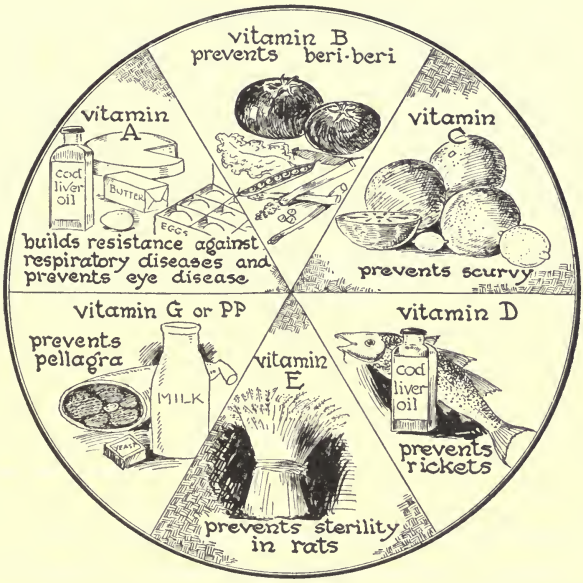
The Vitamins. The vitamins are called after letters of the alphabet, A, B, C, D, E, and G. *Vitamin A* has been found to aid us in resisting colds, pneumonia, tuberculosis, sinus infections, and the like. It is a resistance-building vitamin and also promotes growth. It was first discovered when its absence caused an eye disease in rats and other animals as well as interfering with the body activities. Vitamin A is found abundantly in kale, spinach, turnip greens, and other leafy vegetables, such as cabbage and lettuce, in vegetables containing yellow pigment, such as carrots and yellow corn, and in butter, oils, eggs, and the fat of milk.

Vitamin B also helps growth and seems to aid in building up the nervous system because its lack causes a nervous disease called beri-beri. This disease is very prevalent among people of the tropics whose diet consists largely of rice. Vitamin B is found in vegetables, such as asparagus, cabbage, wheat germs, and tomatoes; in yeast and liver, whole cereals, and milk.

Vitamin C is most common in citrus fruits, such as oranges and lemons, in many other fresh fruits, and in milk. It helps the growth of bone and the teeth and

prevents scurvy, a disease which used to be very prevalent on sailing ships.

Vitamin D has been called the sunshine vitamin because it has been found that the ultra-violet rays of the sun builds this vitamin in the various food substances and in our own bodies. It is found in cod-liver oil, in canned



Read your text carefully and refer to the tables on pages 328–329. Then make a list of all the foods you have eaten in the past 24 hours and check each for the vitamins they contain.

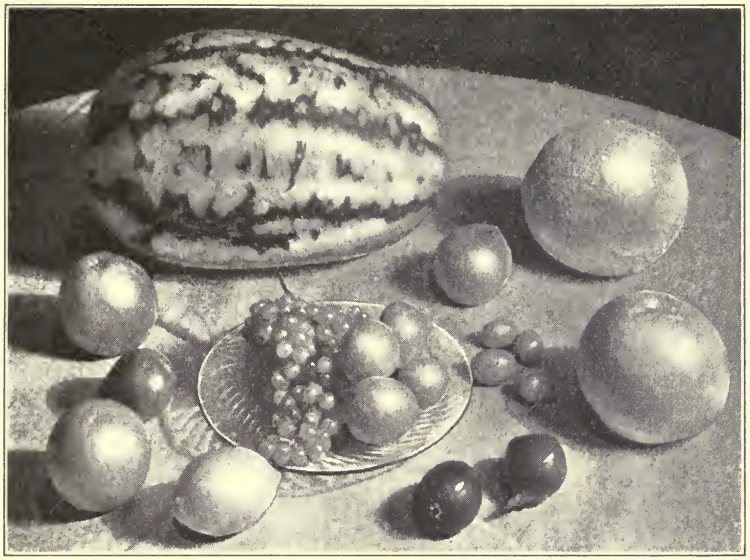
salmon, butter, yeast, egg yolk, and milk. Vitamin D helps to build bones and teeth and prevents rickets, a disease in which the bones lack the proper amount of mineral material.

Vitamin E is found in grains, milk fat, and some meats. Experiments with rats have shown it to be concerned with reproduction, but we are not sure what its effects on man are.

The latest addition to the list of vitamins is *vitamin G, or PP*, as it is sometimes called. This vitamin is found in milk, yeast, lean meat, and some other foods and is believed to prevent pellagra, which has been known in many parts of the South, where people lived, during the winter, on a restricted diet of corn meal, molasses, and fat pork.

The Value of Bulky or Coarse Foods. Vegetables have another value besides that of giving a source of vitamins. It has been found that roughage or coarse, fibrous, and indigestible parts of foods may be of great value in stimulating the lower part of the food tube to pass out the wastes left there. Frequent movement of the bowels is necessary for health, because the waste material kept in the body passes off poisons, which cause us to lose our "pep" and feel constantly tired and out of sorts. Such bulky foods are (*a*) cereals from which the outer coat or bran has not been removed; (*b*) vegetables such as cabbage, lettuce, celery, onions, parsnips, turnips, and the skin of potatoes; (*c*) fruits such as apples, prunes, pears, peaches, raisins, and all fruits in which you can eat the skins.

Values of Fruit in the Daily Diet. There are a good many reasons why we should eat plenty of fresh fruit. In the first place, fruits give us a much better source of sugar than candy because one can satisfy the craving for sweets without danger of overeating. They are good sources of our essential mineral elements and they also contain vitamins A, B, C, and G. We have already said that they help prevent scurvy, and that certain fruits help prevent an acid condition. Fruits also give flavor and palatability to diets and have a laxative effect, thus aiding in elimination of decayed material in the lower bowels. Rather recently fruits have been found to help prevent decay of the teeth. All of these reasons and more can be



Wright Pierce

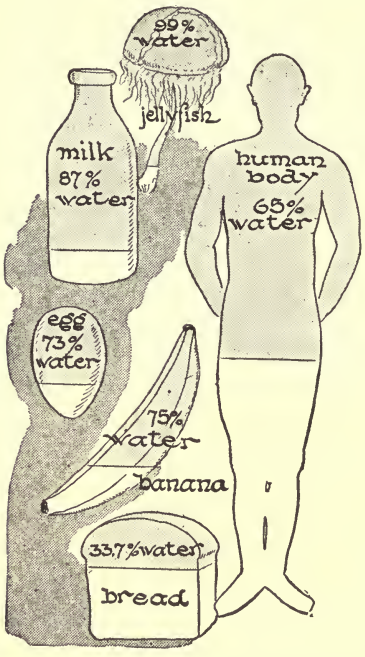
Classify the foods shown here with reference to the vitamins they contain. Can you suggest additions for your own environment?

given which show the reasons for eating fresh fruits at least once a day.

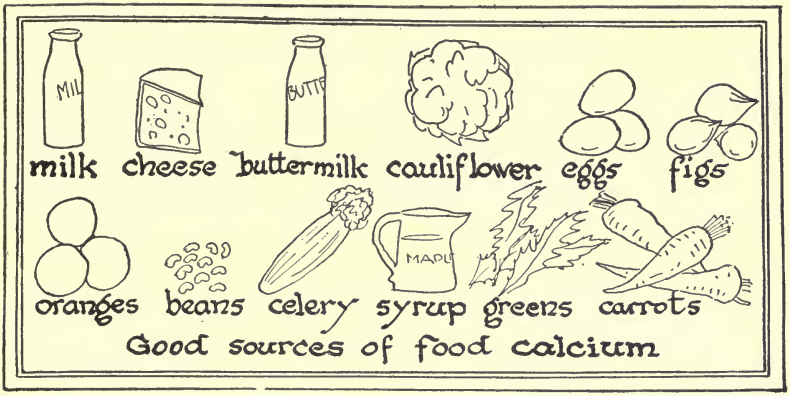
Water as a Regulative Food. Have you ever stopped to think how important water is to living things? Seeds cannot sprout and plants cannot grow without it: all animals are dependent upon it and soon die if their supply is cut off. The human body is over 65 per cent water. Body cells cannot do their work without it, for chemical changes cannot take place unless water is present. Water usually contains mineral salts which are necessary for life. It helps regulate the temperature of the body, it helps dissolve foods so they may be absorbed by the cells, and it aids in the passing off of wastes from the body. Although we take a good deal of water into the body with our foods, for example, in fruits, milk, and other beverages, it is a good plan to get the habit of drinking 5 or 6 glasses

of water a day, especially upon arising and between meals.

The Value of Minerals in the Diet. A chemical analysis of the human body shows that it is made up of about 72 per cent oxygen, 13.5 per cent carbon, 9 per cent hydrogen, 2.5 per cent nitrogen, and about 3 per cent of various mineral salts. Chemically, then, the body is composed of the same substances as the food on which it feeds. Mineral salts, although present in such minute quantities, have been found to be absolutely necessary for life. If the body does not get sufficient iodine, the thyroid gland, found in the front of the neck, is likely to enlarge and form a goiter. Iodine is found in some natural drinking water and not in others. It is also found in foods such as clams, oysters, and fish that come from the ocean. Lime or calcium is needed for building bones and carrying on certain processes in the body. For example, without the presence of calcium our blood would not clot, and we might bleed to death from even the slightest wound. Milk, carrots, and some fruits, especially prunes and oranges, contain a good supply of calcium. Iron is found in the red blood cells, and lack of it causes people to



Everything that is alive or has had life contains some water. Make a list of foods that you think contain a large amount of water.



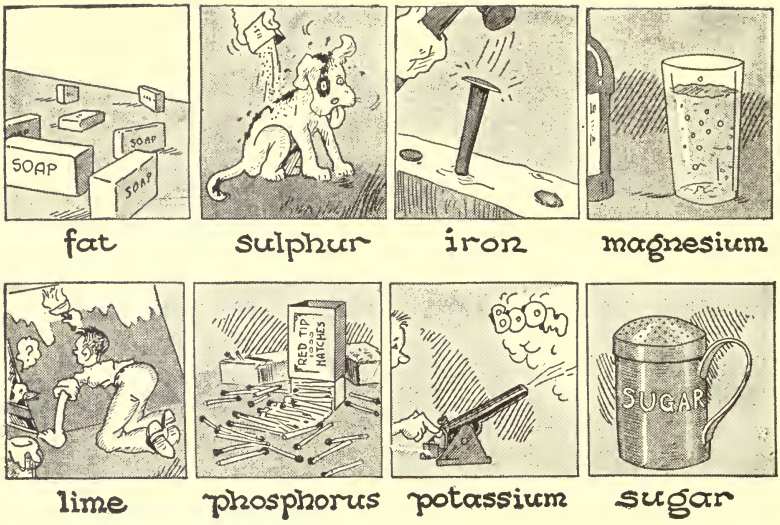
Redrawn from Hygeia

Of what use is calcium to your body?

become anaemic.[1] Iron cannot be used as well by the body in the form of medicine as when in the food. It is found in spinach, string beans, cabbage, egg yolk, beef, and prunes, and to a less extent in carrots and other vegetables and fruits. Phosphorus and sulphur are both necessary in the living matter of the body, and sufficient amounts can usually be obtained from meat, fish, and eggs. Sodium and chlorine are also necessary parts of living material, and are obtained from our table salt which forms a part of the daily diet. Many of the most important body actions, such as the beating of the heart, the contraction of the body muscles, and the work of the nervous system, appear to depend, to some extent, upon the presence of these different salts in our blood.

Someone has said that the body contains sufficient fat to make seven bars of soap; enough sulphur to rid a dog of fleas; enough iron to make a good-sized nail; sufficient magnesium for a dose of magnesia; enough lime to whitewash a chicken coop; enough phosphorus to make 2200 match tips; sufficient potassium to explode a toy cannon;

[1] **Anaemic** (*ȧ-nē'mĭk*): affected with a deficiency in the red corpuscles of the blood.

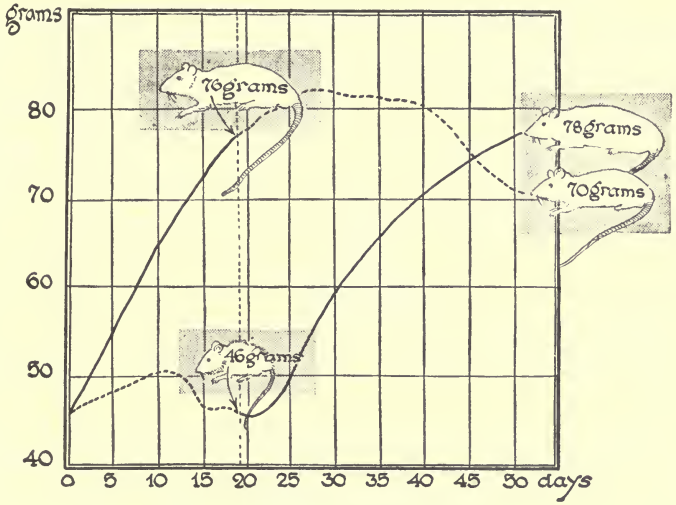


What does this cartoon show?

and enough sugar to fill a shaker. In the form of the chemical substances out of which it is made, the body could be purchased for less than a dollar. But as a living being, man's value cannot be estimated in dollars and cents. For who knows what boy or girl who reads these lines may not make discoveries that will save human lives and alleviate human suffering. Such values cannot be estimated.

The Perfect Food. However, the building and repair of the body is not so simple as this. Living matter contains very small amounts of mineral salts. Such salts may be obtained from vegetables and cereals. But the most important body-building food is milk. We lived on it when we were babies and that is the most rapid growth period in our lives. Milk should always form part of the day's food supply. Not only does it contain proteins, fats, and carbohydrates, but it also has small quantities of lime and other minerals. In addition milk contains

most of the protective vitamins. The experiment shown indicates the value of milk in the diet. Children should have at least one quart of milk a day.



What does this demonstration show?

Demonstration 1. Effect of Milk in Diet of Rats.

Take two white rats of equal size. Weigh them and record their weights. Place them in adjoining cages under the same conditions of air, water, and sunlight. Feed one rat on a weighed ration containing milk, bread, and cabbage. Give the other rat the same amount of weight of bread, cabbage, and water. Weigh each rat at the end of one, two, and three weeks. Are there any differences in weight? How do you account for this difference?

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

oils	fuel	meat	yeast
brown	regulative	minerals	water
protective	citrus	growth	proteins
dairy	vegetables	green	tea
vitamins	mixed	green	milk
coffee	fats	carbohydrates	yellow

A varied diet is important for health because it provides the body with (1)____ foods, (2)____ foods, and those which are (3)____ and (4)____. Fats and (5) ____ are our chief sources of energy and hence are called (6)____ foods. (7)____ build tissues and are (8)____ foods while minerals, (9)____, and water may be considered as (10)____ and (11)____. Minerals needed by the body are found largely in (12)____, milk, and (13)____ (14)____. The six known (15)____ are called A, B, C, D, E, and G. They are found in cereals, (16)____ vegetables, (17)____ fruits, certain (18)____, (19)____, and (20)____ products. Therefore if we are to have all of these in our food, we must have a (21)____ diet. (22)____ is a perfect food because it contains all the nutrients and (23)____ and most of the mineral salts necessary for life.

STORY TEST

Ella Finds She Can Learn Even When She Is Sick

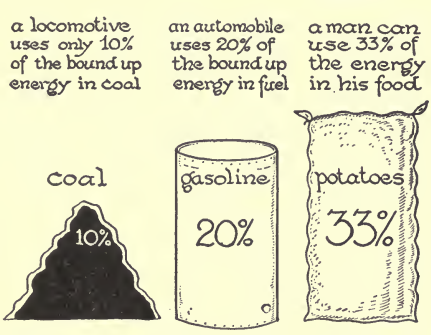
Read carefully and critically. List all the errors and suggest corrections.

I learned a lot from my nurse when I was getting over the scarlet fever. There are three classes of foods. Protective foods which make you strong, like spinach, which has iron; growth foods, like corn and potatoes, which grow in our gardens; and fuel foods, like coal and coke. Heat is just as necessary to run our bodies as to run an engine. The food fuels do not burn with a flame in our bodies but they do unite with oxygen. This happens in the lungs, where we take in air. The best growth foods are those which contain nitrogen. Butter and cheese are good examples of these. There are many different vitamins, but if one drinks lots of milk and tomato juice, he doesn't need to worry about the lack of them. I was surprised to learn that there are more than half a dozen different metals in the body without which we cannot live.

PROBLEM III. SHOULD EVERYBODY EAT THE SAME KINDS AND AMOUNTS OF FOOD?

What Makes the Human Machine Go? If you were to answer this question for your automobile, you would say gasoline, as you would say coal or wood or gas makes the steam engine go. From what you have already learned you know certain kinds of foods have fuel values for the human machine. In the locomotive the energy

in the fuel is released by oxidation in the fire box, as it is when gasoline is exploded in the cylinders of the automobile. In the body the principle involved is the same, foods are oxidized and energy is released. But this is done in the body cells, the oxygen which releases the energy being taken in when we breathe.



Man is evidently an efficient machine as compared with a locomotive or automobile.

The Energy Values of Food Can Be Measured. It has taken a good many men and a large number of experiments to prove that different foods have different fuel values. Just as in measuring distance we use the inch or the foot as a unit of length, so we use a unit of heat called the Calorie. This is roughly the amount of heat needed to raise the temperature of one pound of water 4 degrees Fahrenheit. Thus it became possible to estimate exactly how many units of heat were locked up in given amounts of different kinds of foods. It has been found that a given weight of fat will furnish about twice as many Calories as the same weight of carbohydrates or proteins.

Should We Count Our Calories? After knowing the number of Calories in different foods, the next step was for scientists to find out the Calorie requirements of the human machine. As you can see, these requirements would not always be the same. Any one who does hard work requires more energy-producing foods in a given time than when he is sitting quietly at home. An adult resting quietly in bed needs only from 1500 to 1800 Calories a day, depending on his weight, while the same man, doing hard muscular work, would need at least 4000 Calories a day.

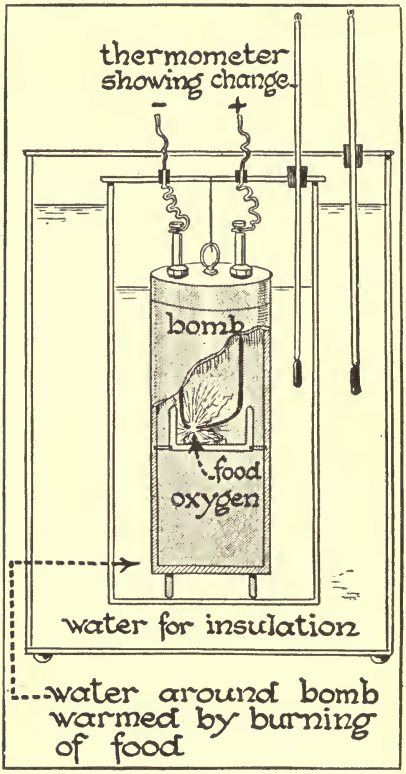
							MINERALS			VITAMINS				
		WT. GRAMS	CALORIES	WT. FAT GRAMS	WT. CARBO. GRAMS	WT. PROT. GRAMS	CALCIUM	PHOSPHORUS	IRON	A	B	C	D	E
BEVERAGES														
Cocoa	1 cup	255	240	12	24	9.5	XXX	XXX	X	XXX	XX	X		
Grape Juice	1 cup	199	200		50		X	X	XX	XX	XX	XX		
Orange Juice	1 cup	232	100		25				X	XXX	XX	XXX		
BREADS														
Coffee cake	3″x3″x4″	117	333	12.08	48	8		X		X	X			
Muffins, graham	1 large	78	200	3.5	35	6.5	X	XX	X	X	X			
Waffles, plain	1 6″diam.	26.7	100	4	12.5	3.5	X	X		X	X			
Rolls, French	1 roll	36.8	100	1	20	3		X		X	X			
Ham sandwich	1 slice 2″x4″x⅝″	39	200	14	13.7	5		X	X		X			
Lettuce and tomato sandwich	1 slice 2″x4″x⅝″	59	108	6	11	2	X	X	X	XX	X			
CAKE														
Gingerbread	1″x1⅔″x2″	31	100	2	18	2	X	X	X		X			
White	1½″x2″x1″	42	135	5	16	3	X	X		X				
CEREALS														
Farina *	¾ cup	170	100	.5	21	3		X		X	XX			
Oats, rolled *	1 cup	280.5	100	1.83	16.67	4.2	X	XX	X	X	XX			X
Wheat, shredded	1 bis.	27.4	100	.49	20.59	3.51	X	XX	X	X	XX			X
CRACKERS														
Saltines	6	23	98	3	15	2.4								
Uneedas	4	28.4	105	2.3	19	2.5								
FATS														
Butter	1 Tbsp.	13	100	11		.13				XXX	X		X	X
Olive Oil	1 Tbsp.	11.11	100	11.11										
FRUITS														
Apple §	1	212	100	.64	23	.64			X	X	X	XX		
Canteloupe §	1 4½″diam.	510	100		24	1.5			XX	XX	XX	X		
Figs, dried	1½ large	31	100		24	1.4	X		XX		X	X		
Oranges §	1 large	268	100	.3	23	1.61	X		XX	X	XX	XXX		
Peaches, fresh §	3 med.	290	100	.3	23	1.5	X	X	X			XX		
Prunes, stewed	2 & 2 T. juice	60	100		24	.5	X		X		XX			
NUTS														
Brazil nuts	2 nuts	15.5	100	9.5	1	2.5					XX			
Peanuts, sh'l'd single nuts	20-24	18.2	100	7	4.5	4.69	X	X	X	XX	XX			
PIES														
Apple	4½″arc	136	300	13.8	42	2.25	X			X	X			
Custard	4″arc	118	200	7.2	29.5	4.5	X	X		XX	XX			
Lemon meringue	3″arc	85	450	13.5	76	5.8		X			X			
Raisin	4⅛″arc	85	256	9	52	2.25	X	X	X	X	X			
EGGS														
Plain	1⅓	67.5	100	7.09		9.05	X	X	X	XXX	XXX	X	X	X
FISH														
Creamed codfish	½ cup	60	100	5	5.5	8	X	X	X	XXX	XX	XXX		
Mackerel, broiled	4″x2″x1½″	62	100	5		14	X	X	X					
Salmon, canned	½ cup	52	100	6		11	X	X	X	XX	X			

* Cooked § As purchased

							MINERALS			VITAMINS				
		WT. GRAMS	CALORIES	WT. FAT GRAMS	WT. CARBO. GRAMS	WT. PROT. GRAMS	CALCIUM	PHOSPHORUS	IRON	A	B	C	D	E
CHEESE														
American, pale	½″ cube	22.8	100	8	.07	6.5	xx	xx		xx	xx			
MEATS														
Chicken meat	1 med. slice	55	100	5.57		12.5		x	x					
Beef, round pot roast	1 slice	43	88	5		13		x	x					
Steak, broiled club	3″x2½″x½″	51	100	6.5		10		x	x					
Lamb, chops, broiled	1large2″x2″x1½″	46	100	6.5		10		x	x					
Pork, bacon	4-5 small pcs.	14	100	9.5		3		x	x					
Ham, boiled	4¾″x4″x⅛″	37	100	8		7		x	x		xx			
Hamburger	2½″diam.x1″	56	100	5		14		x	x	x	xx			
Frankfort	¾ of link,3¾″l.	40	100	7.4	.44	7.8		x						
MILK														
Whole	⅝ cup	144.5	100	5.8	7	4.7	xxx	xx		xxx	xx	x	x	x
Malted	2 Tbsp.	25.7	100	.77	19.71	3.57	xx	xx		x	xx	x	x	x
PUDDINGS														
Bread pudding	¾ cup	66.8	259	12	8	29	x	x		x	x			
Cup custard	¾ cup	210	225	9	25	10	x	x	x	xx	x			x
SALADS														
Combination	½ cup	90	34	.2	6	2	xx	xxx	xx		xx	xx		xx
Fruit	½ cup	87	198	16	11	2	x		x	xx	xxx	xxx		x
Lettuce, French dressing	1 serv.	78	237	25	2	.8	xx	xxx	xxx	x	xx	xxx		xx
Tomato and lettuce	1 serv.	149	194	19	5	2	x	xx	x	xxx	xx	xxx		x
Salad Dressings														
French	2 Tbsp.	24	133	15										
Mayonnaise	1 Tbsp	14	100	10	.6	2		x		x	xx			
SOUPS														
Consomme	1 cup	214	5		.2	1								
Cream of clear tomato	1 cup	240	269	19	18	7.5	xx	xx	x	xx	xx	xx	x	x
Split pea	1 cup	260	93	.04	12	10	x	xx	xx		xx	xx		x
SWEETS														
Chocolate fudge	1½″x¾″x1″	25.5	97.8	2.2	19	.5	x	x	x	xx	x			
Jelly beans	6½ large	28	100		24	1								
Nut bar	2⅓″x1″	62	330	14	47	4	x	x	x	x	x			
Suckers	1⅓	26	100		25									
VEGETABLES														
Asparagus	5 stalks	112	25	.13	13.82	2.07	x	xx	xx		xxx			
String beans	1 cup	108	45	.32	7	2.44	xx	xx	xx	xx	xx	x		
Cabbage, shred'd	1 cup	63.3	20	.19	3.55	1.01	xx	x	xxx	x	xx	xxx		
Corn on cob	1 ear 6″	130	100	1	19.5	3	x	x	x	x	xx			
Onions	3 or 4 med.	205	100	.62	20.33	3.3	x	x	x		x	xx		
Peas, canned	¾ cup	180.5	100	.36	17.73	6.52	x	xx	xx	xx	xx			
Potatoes, plain	1	120	100	.12	22.09	2.64	x	x	x	x	xx	x		
Tomatoes, canned	1¾	442	100	.88	17.70	5.31	x	xx	x	xx	xx	xxx		
Sauerkraut	3 Tbsp. heap.	100	16		3	1	x	xx	x	x	xx	x		

After Tables of Food Values, A.V.Bradley, Santa Barbara State Teachers College, Santa Barbara, Calif.

More Food Needed during the Growing Period. It is an old saying that growing boys need more food than grown men. Experiments have proved this to be true. Rapidly growing boys between the ages of 10 and 15 need about 2500 Calories a day, while girls of the same ages require about 2000 Calories a day, older girls requiring a little more and younger girls a little less than this amount. The table on page 331 gives an estimate based on body weight. It will be seen that as we grow older, we require fewer Calories per pound. You can see why this is so, for after we become adults, the body does not grow much in size. Food is required for repair purposes and for the release of energy but not for rapid growth. So we see the hearty appetites of growing boys and girls have a scientific basis.



The bomb calorimeter is used to find out the fuel value of food. Can you explain how it works?

Seasonal Differences in Food Requirements. Every one knows that in hot weather we are not so hungry as in cold weather. Have you ever stopped to think why this is so? The body has a temperature of 98.6° F. In cold weather more heat is lost than in warm weather,

so we need more fuel foods. Then we are likely to exercise harder in cold weather — which means more food and more fuel food. We find the inhabitants of the polar regions live largely on animal fats and meats, while those living in the tropics eat largely fruits and vegetables with little meat. Can you give at least two reasons why this is so?

Calories needed daily for each pound of body weight

Under 1 year	40 to 43
during 2nd year	40 to 43
during 3rd year	37 to 40
during 4th year	37 to 40
during 5th year	35 to 37
during 6th year	34 to 35
during 7th year	32 to 34
during 8th year	30 to 35
during 9th year	30 to 35
during 10th year	28 to 32
during 11th year	28 to 32
during 12th year	28 to 32
during 13th year	25 to 30
during 14th year	20 to 25
during 15th year	20 to 25
during 16th year	20 to 25

17th year and up depends on body activity

All Types of Foods Necessary. We must not think because we can estimate our needs in Calories that we should eat only fuel foods. Body-building foods are necessary as are regulative and protective foods. But protein foods can be used to release energy as well as to build and repair tissues. And many of our regulative foods, especially vegetables and fruits, are good sources of energy. In selecting foods the most important rule is to get a variety of foods, for in this way we will meet all the body needs.

What Proportion of the Diet Should Be Proteins? Experiments have been made that show that as Americans we eat relatively more proteins than many other peoples. Most people eat too much protein food and not enough green vegetables and fruits. It is estimated that about

15 per cent of our total Calories should come from proteins. One widely used standard says a ratio of 1 Calorie from proteins, 3 from fats, and 6 from carbohydrates is about right, although others believe that a ratio containing even less protein is desirable. Later we will find that not all proteins are equally valuable for building body cells, so the *kinds* of proteins as well as the *amounts* used are important in making up a diet. Young people need relatively more protein in the diet than do older persons, because they lead more active lives and are growing. For such, proteins should come largely from eggs, milk, lean meats, and whole-grained cereals.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

carbohydrates	ounce	Fahrenheit	differ
quiet	Centigrade	15 per cent	proteins
energy	Calories	less	weight
fats	four	six	5 per cent
two	protein	cells	loses
oxidation	oxidized	25 per cent	eight
Calorie	gains	more	active
pound	50 per cent	gram	less

In the human machine just as in the automobile the (1)____ which makes both go comes from the (2)____ of fuel. In the human machine the food is (3)____ in the (4)____ of the body, thus releasing the (5)____ where it is used. The unit of heat used in measuring energy released from foods is called the (6)____. It is the amount of heat necessary to raise the temperature of a (7)____ of water (8)____ degrees (9)____. (10)____ give about twice as much energy as do (11)____ or (12)____. The (13)____ requirements of the body (14)____, depending upon age, sex, season of the year, and kind of work done by the individual. A rapidly growing boy or girl needs (15)____ food than does an old man, because the former is making new (16)____ and thus gaining in (17)____. A person needs more (18)____ in winter than in summer, because the body (19)____ heat more rapidly then and

we are usually more (20)____. About (21)____ of the Calories in one's diet should come from (22)____ or a ratio of 1 : 3 : 6 should be maintained between our (23)____, (24)____, and (25)____.

STORY TEST

Bob May Be a Better Engineer than Doctor

Read carefully and critically. List all the errors and suggest corrections.

Just as it takes fuel to run a gasoline engine so it takes fuel to run the human engine. The energy value of foods is measured in Calories. A food Calorie is the amount of heat that will warm one pound of water 1° F. Children of junior high school age require less food than their parents because of their smaller size. It is the oxidation of food that gives us heat to keep the body temperature up to normal, 89.6° F.

Last winter I had the grip, and developed a temperature of 104° F., so the nurse said, but I think she was wrong because I was eating less food than when I was well. It is a good plan to check your weight by standard weight tables to see whether you are of proper weight for the best health. If you are too heavy, stop eating protein because they are building foods. This will give you less variety, but the only reason for a varied diet is because one is likely to tire of a food unless he has a change often.

PROBLEM IV. WHY DO FOODS SPOIL?

What Causes Food to Spoil. It is a matter of common knowledge that foods become unfit to eat if they remain for any length of time exposed to air in a warm place. They smell badly and probably taste worse. Sometimes fuzzy growths which we call mold appear on them. Fruit juices usually taste as if they had alcohol in them. Many kinds of tiny plants cause these changes.

Demonstration 2. To Show Action of Bacteria, Yeasts, and Molds.

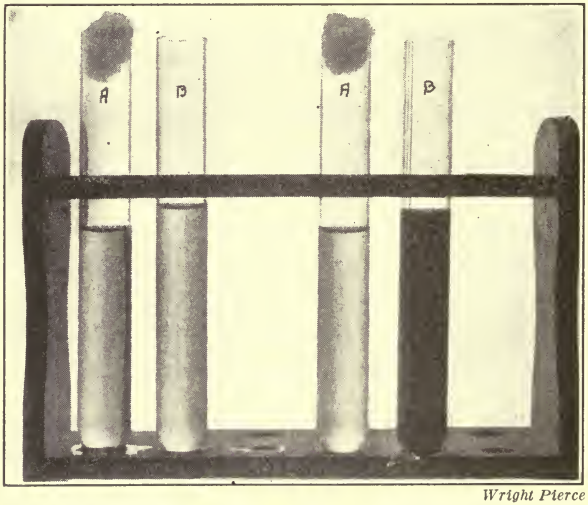
Make a solution of molasses and water, using about one part of molasses to five parts of water. Put the solutions in two cups: one exposed to the air in a warm place, the other kept as near the ice as possible in the icebox. Observe the appearance of the contents of the two cups from day to day. Is there any difference in the odor? Is there any difference in taste? How do you account for these changes?

Moisten a slice of bread and expose it to the air of the kitchen for a half hour and then place it in a jar and cover lightly. Keep the bread moist and in a warm place. Place a slice of dry bread in another jar and screw the cover on tightly so that no dust or air may enter. Note the appearance of the bread in the two jars from day to day. What is happening to the moist bread? Leave it for several days. What happens to the color of the fuzzy growth on the bread?

When examined with the lens, the dark objects will be seen to be filled with tiny bodies called *spores*. These spores get into the air, settle on food, and develop into mold.

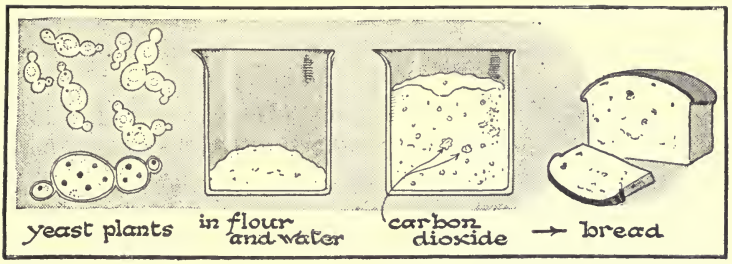
Expose to the air in a moderately warm location a few moist beans in a cup. Place an equal number of dry beans in another cup. Examine after a day or two. What has happened to the moist beans? Do they look different from the dry beans? Is there any odor present? What causes it?

The changes that we have just observed are caused by tiny organisms, most of which are far too small to be seen without the aid of a compound microscope. Hence they



Wright Pierce

This picture shows at the left two tubes of sterilized beef broth, a good substance for the growth of bacteria. One tube was plugged with absorbent cotton, the other left open. Both tubes were left in a warm place for a week. At the end of this time the contents of tube A was unchanged while that in tube B smelt and tasted of decay. How do you account for this?



When yeast plants grow they break down their food into carbon dioxide and alcohol. How would this account for the rising of bread?

are called *microorganisms*. They include the bacteria, yeasts, and molds. Bacteria multiply with very great rapidity once they get a favorable place in which to live. They must have dead or living foods in order to grow, since, unlike green plants, they cannot make their own food. Yeast and molds likewise grow rapidly when food and temperature conditions become favorable. We know that the action of bacteria will cause the decay of various organisms. Sometimes they give up poisons as a result of their growth. Some will cause milk to sour and some will even cause diseases of various kinds. These tiny plants, yeasts, molds, and bacteria, are always present in the air although we cannot see them, and when they settle upon foods and grow rapidly, they cause the foods to spoil, changing both the taste and odor.

Yeasts and Their Work. Every one knows that yeast under certain conditions of warmth and moisture causes bread dough to "rise," but it is not so well known that this condition is caused by the growth of millions of tiny one-celled plants which were in the compressed yeast cake. Wild yeasts occur almost everywhere and, under favorable conditions, cause the process of *fermentation* to take place. In this process the yeast plants break down the sugar and starches on which they feed into carbon dioxide and alcohol. Yeast plants often get into sweet foods,

especially fruits, causing them to ferment or "work" and become unpleasant to the taste.

Molds in the Home. Mold is one of the most common enemies of food in the home. Molds do considerable damage, although they do not necessarily render food unfit to eat. You may remember scraping the layer of mold from cheese before using it. As a matter of fact, certain cheeses get their flavor from the molds that grow in them. Molds attack other substances besides food, and frequently grow on shoes, leather, paper, or moist wood.

Proof that Bacteria Are Living Things. How do we know that bacteria cause decay? We cannot see bacteria unless we have a powerful microscope, but it is possible for us to prove that bacteria really do cause things to

Preparing Petri dishes for an experiment. After the culture media is poured into the dishes they are sterilized again to make sure no germs got in from the air before the dishes were covered.

decay. This can be easily done by a simple experiment. It has been found by scientists that bacteria grow well in a medium made by cooking beef broth with either gelatin or agar, a substance obtained from a Japanese seaweed. It is poured, while still boiling hot, into small Petri dishes. These are glass dishes (see picture, page 336), which have loosely fitting, overlapping covers. Then the dishes and their contents are heated in order to kill all life that might exist in them.

Colonies of bacteria growing on culture media in a Petri dish.

After one of these dishes has cooled, it is exposed to the air for a very short time and then covered and put in a warm place. Another dish containing media which was not exposed is left as a *control.* If these dishes are left in a warm place for two or three days, spots appear on the surface of the culture medium of the dish that was exposed. These spots may be gray, orange, brown, or even red in color. If a tiny speck from one of these spots is removed and examined under a high-powered microscope, it will be found to be made up of great numbers of tiny rod, spiral, or ball-shaped bodies. These bodies have been proven by scientists to be bacteria. If some of these bacteria are placed on food, they will develop rapidly into more colonies of bacteria of the same kind and the food will spoil. Thus we

Three forms of bacteria. Are all exactly alike within a given group?

know that bacteria present in the air under certain conditions will grow in foods and will cause foods to decay.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

grow	vacuum	dark	dryness
light	plants	excessive	circulation
odor	moderate	animals	ferment
moisture	vitamins	decay	appearance

Foods spoil because tiny (1)____, yeasts, bacteria, and mold, grow in them. Experiments have shown that (2)____ and (3)____ temperature as well as some protein food, which is living or dead, are all factors favorable to the growth of bacteria. Bacteria grow more rapidly in the (4)____ than in the (5)____. Microorganisms cause food to spoil. Bacteria cause it to (6)____, yeast causes it to (7)____, while molds may change its (8)____ and give it an unpleasant (9)____.

STORY TEST

Roy May Become a Biologist

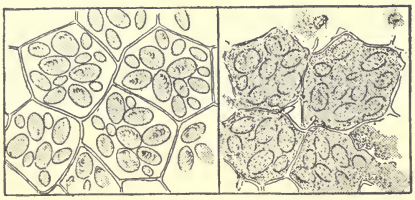
Read carefully and critically. List all the errors and suggest corrections.

I used to think it rather funny that they called bacteria and yeast, plants when you couldn't even see them. Molds seem like plants, at least you can see them. I made some root beer by putting yeast into a prepared sugar solution, with some root extracts. I could see bubbles of gas as it worked. This is the same kind of change that occurs when bacteria in milk cause it to sour. The same gas is given off in both cases. Plants that we can barely see with the unaided eye are called microorganisms. When microorganisms take root and grow in our foods, the food may acquire a changed and more pleasing taste as is the case, sometimes, with cheese and butter. Or it may produce an offensive odor and taste. Bacteria are seen under the microscope to have three common forms or shapes. They are rods, circular, and ball shaped.

PROBLEM V. HOW MAY WE KEEP FOODS FROM SPOILING?

How May We Keep Foods from Spoiling? We have seen from what has just been said that bacteria live and grow under certain favorable conditions. Our next question will be to find out what unfavorable conditions will prevent the growth of these organisms.

What Cooking Does to Foods. If we examine a bit of raw potato under the microscope, we find that the starch contained in it is in little cells surrounded by thick walls. If we examine a bit of well-cooked potato under the same microscope, we find the cell walls have largely disappeared. Cooking softens and breaks down these tough walls and makes vegetables and meat less tough and more palatable, thus aiding digestion. More than this, cooking makes foods safe, as it destroys germs and other living organisms which might grow if taken into the body. Cooking, with the addition of salts and condiments, improves the flavor of foods.



The effect of cooking on the cells of potato. Notice the walls of the cells and the enclosed starch grains in the uncooked potato. What has happened in the right-hand figure?

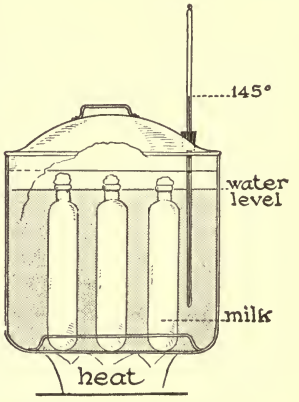
Home Experiment. What Temperature Is Unfavorable for the Growth of Microorganisms? Take a small number of beans, soak them, and put an equal number in three cups containing small amounts of water. Place one cup in the ice box near the ice; another in a moderately warm place; and the third in the oven or some place where it is exposed to rather high heat. Be sure to keep the amount of water in each cup about the same. Examine the cups from day to day. In which one of the three cups do you find the most decay? Observe the growth of mold in bread and the growth of yeast in a molasses solution in cold, moderate, and very warm temperatures. What results do you obtain?

Conclusion. What conditions are unfavorable for growth?

The Value of Sterilization. These experiments show rather conclusively that very hot and very cold temperatures are unfavorable for the growth of bacteria, yeast, and molds. Most bacteria are killed after boiling for ten minutes, or exposure to dry heat of 212° for about the same length of time. Heating substances for a long enough period to kill all bacteria is called *sterilization*. It is a process used in canning vegetables and fruits. We cook our foods, and we put them in cold storage or ice boxes in order to keep them. Other experiments made with bacteria show that bacteria must have moisture in order to grow; that the bacteria must have a moderate temperature; and that food substances must be present. Proteins seem to be the substances most favorable to their growth. It has also been found that light is unfavorable and darkness is favorable for the growth of many microorganisms.

What is this girl doing?

Milk and Bacteria. Milk is not only a perfect food for man, but it is also a perfect food for bacteria. Since it is one of our most important foods, and one that easily spoils, great care must



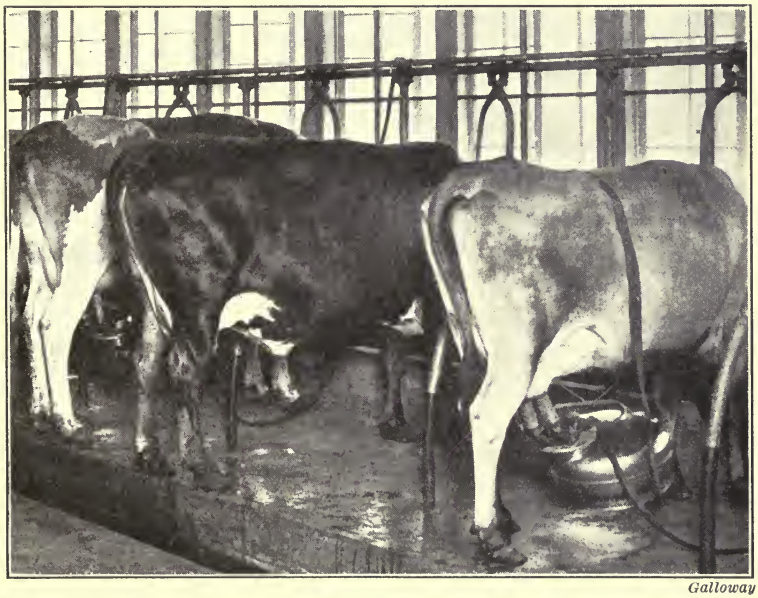
Describe the use of this apparatus. How could you make one for home use?

be taken in handling it so that dirt and disease germs do not get into it.

Milk should be kept cold and covered, from the time it leaves the cow until the time it is used. Since milk is the best food for young children and since a baby's digestion is easily upset, we must keep milk free from harmful bacteria. To kill bacteria without injuring the milk, a process known as *pasteurization* is used. This is named after the great French scientist, Louis Pasteur, who first used the process to kill harmful organisms in wine.

Demonstration 3. How to Pasteurize Milk.

Fill each of two test tubes half-full of raw milk and plug both tubes with clean absorbent cotton. Place one tube in a beaker of water and heat it to 145° F. for 25 or 30 minutes, and cool it in cold water. Set the two tubes aside so that they will both be



Galloway

Milk from this dairy is a safe food for babies. Why? Name all the devices which make clean milk possible.

under the same conditions of temperature. Examine the tubes at intervals of 24 hours for three or four days. Note the taste and odor of each.

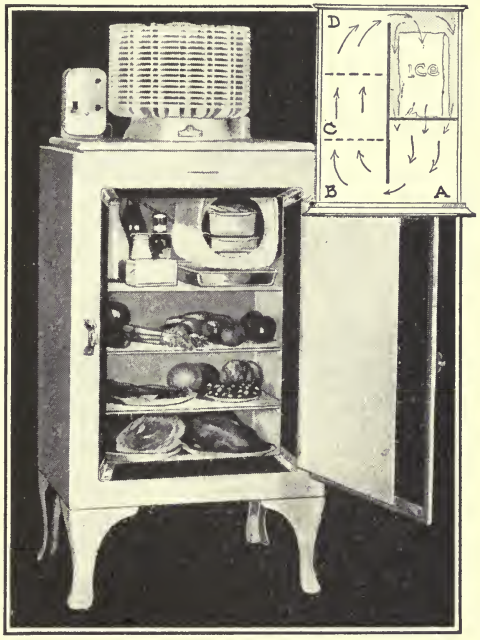
Raw Milk and Pasteurized Milk. Careful pasteurization will not harm milk, but if the temperature is raised too high, the Vitamin C in the milk will be destroyed and thus the milk will not be of as much value as a food. A special grade of raw milk called certified milk is now sold in most communities. The price is higher because of the special care taken in producing and handling it.

A Cold Temperature Unfavorable to Bacteria. If you will think back to the experiments on bacteria, you will recall that *cold* is unfavorable for the growth of bacteria. However, some bacteria will live in ice for a long time. Intense cold prevents the growth of bacteria, but it does not always kill them. We have come to make use of this knowledge in our homes by using refrigerators. A well-made electric refrigerator or even a good ice box will keep the temperature below 45° F., which is sufficient to prevent bacterial growth and will keep foods from spoiling before they can be eaten.

Construction of the Refrigerator. The household refrigerator is a large box with thick, heat-insulated walls, and with doors or covers to the several inside compartments. There is always one chamber for the ice or the ice-making machine, and another with shelves for food. These compartments are connected by tubes or openings, so that there is a free circulation of air throughout the entire refrigerator. The drainage pipe leads to a pan, or to a waste pipe protected by a trap that prevents warm air from coming in.

How We Use the Refrigerator. When air comes in contact with ice, it gives up its heat, becomes colder and heavier, and sinks to the bottom of the ice chamber. An outlet below the ice allows this cold air to pass out

at one side to the bottom part of the refrigerator, where warm food substances give off their heat to the cold air, which is warmed and gradually rises, passing in again at the top of the ice chamber. Thus we have a circulation of air within the refrigerator. The warm air returns to the ice which absorbs heat in the process of melting and the heat is carried off in the water which drips into the drain pipe.



Are the foods properly placed in this electric refrigerator? Explain how the cold air circulates.

Electric and Other Methods of Refrigeration. The application of the cold-storage plant to the home is found in the newer types of refrigerators which run by electricity or by gas. These automatic refrigerators are more expensive in the first cost than ordinary ice boxes, but they have the advantage of being able to keep a nearly constant temperature all the time and they are economical to run. Since these automatic devices are colder than the ordinary refrigerators using ice, the arrangement of foods in them is of less importance.

A New Development in Refrigeration. One of the latest developments in refrigeration is the use of "dry ice," which is solid carbon dioxide. This has the advantage of

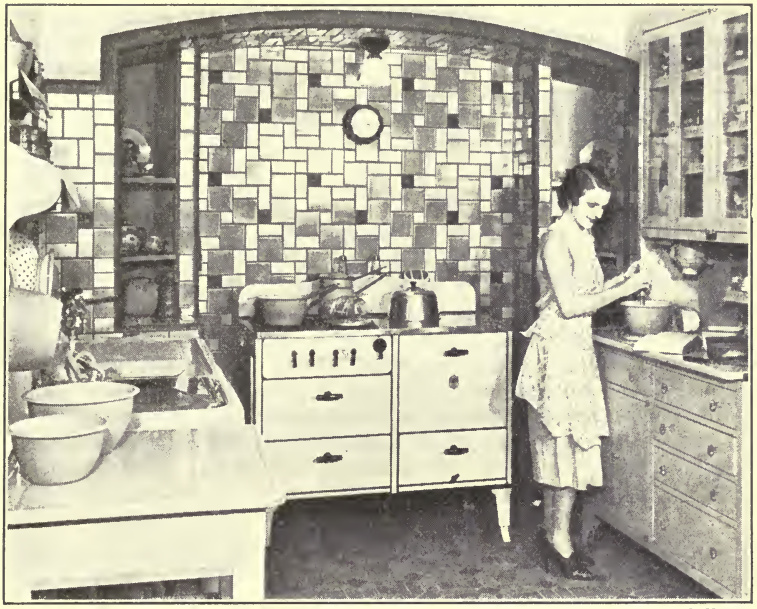
being about 140° F. colder than ice itself, and hence a small cube of it will do the work of a much larger piece of ice. In addition, dry ice lasts longer than ordinary ice. A forty-pound piece uncovered in a store window during the summer would last about twenty-four hours. Dry ice evaporates slowly without leaving any liquid behind to rust or corrode the container. At present, it is used in the refrigeration of perishable foods in transit, and particularly for the transportation of small packages of ice cream.

What is "dry ice"? Is it really dry? What are the advantages of dry ice?

The Iceless Refrigerator. In hot countries, one finds porous skins and unglazed earthenware vessels filled with water hanging in a breeze in the shade. The natives have learned that the water gets cooler when so treated, though they do not understand why. When water evaporates, it absorbs heat. If you wet your hand and swing it in the air, it feels cooler. This is due to the absorption of heat during evaporation.

Thermos Bottle. The thermos bottle is really a double-walled bottle, or one bottle inside of another with a vacuum between them. A vacuum is a better insulator than air. The inside walls of the bottles surrounding the vacuum are mirrors which reflect the heat rays and prevent their passage across the vacuum.

A Clean Kitchen Necessary. Since foods are handled in the kitchen, it goes without saying that a clean kitchen will aid greatly in preventing the spoiling of foods. All surfaces in the kitchen should be washed frequently. Wooden surfaces, especially when they become greasy, make excellent dwelling places for bacteria. For this reason tiled surfaces are more hygienic than wood. Re-



Galloway

Make a list of all the hygienic and all the labor-saving devices found here.

member that the hands must be kept clean when handling foods. Since flies carry disease, the kitchen should be well screened. Dishes should be washed clean with plenty of soap and rinsed with very hot water.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

low	100°	30	50
clean	spreading	C	screened
vitamin	nutrient	circulation	E
refrigeration	10	vacuum	dry
digest	evaporation	prevent	sterilization
A	pasteurization	start	high
60	145°	212°	D
B	kill	ice	dirty

We cook foods because the (1)____ temperature kills the germs and because the cooking softens tough fibers, thus making food taste better and (2)____ more easily. Heating substances for a period long enough to kill germs is called (3)____. Cold will (4)____ the growth of bacteria, but it does not always (5)____ them. Milk, even when handled under the most sanitary conditions, spoils very easily. One way to help prevent its spoiling too soon is a process called (6)____. In this process the milk is heated to (7)____ F., for a period of (8)____ minutes. Heating the milk to too high a temperature destroys (9)____ (10)____ and makes the milk less useful. Cold as well as heat is used to prevent food decay. (11)____ of air is important in (12)____ because it helps to keep the constant low temperature. Electric (13)____ and the use of (14)____ (15)____, are two modern methods of refrigeration. Thermos bottles use a (16)____ to keep the temperature constant. Water may be cooled in iceless refrigerators by the action of (17)____. Since bacteria cause foods to spoil, the kitchen should be kept spotlessly (18)____. It should be well (19)____ to prevent the (20)____ of germs by flies.

STORY TEST

Paul Was Absent Just One Day from Class

Read carefully and critically. List all the errors and suggest corrections.

Of the many things that cause milk to spoil bacteria are the worst, but they can be checked by cooling and killed by freezing. One common cause of milk souring is the thunderstorm and there is no help for it. If you wish to prevent mold from forming on food, you can do any one of three things. Keep it cool, keep it hot, or keep it very moist. Since microorganisms are plants, they die if kept away from the sunlight very long. In canning fruits and vegetables, it is necessary to heat them to 144° F. in a process called Pasteurization. They must then be quickly put into cans and sealed so that they are air-tight. Foods so preserved will keep indefinitely. The principle of the electric refrigerator is that the refrigerator has electric insulation in all the walls. An ordinary refrigerator keeps just the heat out, but the electric refrigerator keeps both electric and heat energy out.

THE REVIEW SUMMARY

In preparing a summary of what you have learned in this unit, you will want to place emphasis on the big ideas which have come

out of the applications of the facts you have learned and the demonstrations you have seen. For this unit they are as follows:

1. We need a variety of foods.
2. Foods come from plants, animals, and inorganic matter.
3. Foods are used for growth, energy, and regulation of the bodily activities.
4. Vitamins are essential to life.
5. Milk is the one best food.
6. Bacteria cause foods to spoil.
7. Refrigeration, drying, preserving, and cooking protects foods.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the other place all the numbers of the statements you believe to be incorrect. Your grade = right answers* $\times$ 2.

I. **Organic foods are necessary for plants and animals because:** (1) living matter contains the same chemical substances as foods; (2) they grow and some foods are needed for growth; (3) living things do work and some foods are oxidized to release energy; (4) they need mineral salts; (5) when a plant wilts it needs organic food.

II. **Green plants:** (6) are the food producers of the living world; (7) make food only when in the sunlight; (8) do not use the foods which they manufacture; (9) get the energy to do their work from the sun; (10) utilize the wastes from animals in making organic foods.

III. **A varied diet is necessary in order:** (11) to get a variety of food; (12) that we will not tire of food; (13) to get vitamins, minerals, and all the foods which help to build and regulate the body; (14) to keep enough of the different kinds of food on the earth; (15) to give us necessary growth foods.

IV. **Proteins must be a part of the daily dietary because they:** (16) make us strong; (17) contain much iron; (18) contain the necessary materials for body growth; (19) give us the best supply of vitamins; (20) release more energy than other foods.

V. **Green vegetables should be included in the daily dietary because they:** (21) supply us with many necessary minerals; (22) are our best sources of fat; (23) are all rich in proteins; (24) supply vitamins; (25) supply energy at low cost.

VI. **We must count our Calories in our food because:** (26) it is the fashion to do so; (27) each one of us needs a given number of Calories, depending upon the work we do; (28) overweight people need fewer Calories than underweight people; (29) age, weight, and occupation demand a different number of Calories; (30) young people need more Calories than older people.

VII. **Refrigeration:** (31) is one means of keeping foods from spoiling; (32) uses well-insulated containers to regulate temperature; (33) kills germs because its temperature is so low; (34) makes possible the transportation of milk for long distances; (35) is economical because it keeps foods fresh for such a long time.

VIII. **Foods may be kept from spoiling by:** (36) drying them so that bacteria will not grow; (37) putting them in a cold ice box; (38) sterilizing them; (39) adding salt, sugar, or other preservatives to them; (40) eating them as soon as they are cooked.

IX. **Milk is the best food for young people because it:** (41) contains a good deal of protein; (42) contains all the body-building and body-regulating foods; (43) contains vitamins; (44) is our best source of calcium; (45) is very cheap.

X. **Cooking is useful because it:** (46) kills germs; (47) makes foods taste good; (48) softens food so that it may be easily digested; (49) makes possible the addition of fat in frying, which aids in digestion; (50) makes meats more palatable.

THOUGHT QUESTIONS

1. Suppose you live in a part of the country that has a deficiency of iodine in its water supply. What should you do about it?

2. Devise an experiment by which you can prove that bacteria and not molds are responsible for the spoiling of some particular food. Show all the steps of the experiment, tell what foods you would use for it, and just how you could prove your point.

3. Determine which would be cheaper for a five-year period, an ice box which cost originally $70 and which uses 700 pounds of ice a month at 60¢ a hundred, or an automatic iceless refrigerator that costs $300 and costs $2 a month to operate. Allow 50¢ a month for food saved by the iceless refrigerator over that saved by the ice refrigerator and charge 6% interest on the investment.

4. What processes are dependent upon yeast?

REPORTS UPON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit.
2. Interesting foods of peoples in distant lands.
3. Different ways in which wheat appears upon our dining table.
4. Variations in the temperature of the human body.
5. The value of hunger.

SCIENCE RECREATION

1. Obtain starch from potatoes.
2. Test and preserve eggs for home use.
3. Plan an experiment to show that protein food is the most favorable kind of food for bacteria.
4. Read Cather's *Shadows on the Rock*, pages 46 to 47, to see how the people of Quebec lived in winter during the early days.

SCIENCE CLUB ACTIVITIES

1. Visit a flour mill to see how flour is made.
2. Visit a large dairy to see how milk is protected.
3. Make a list of all the candy you eat for a week, giving the time of day when you ate it. Can you improve your diet by substituting other sweet fuel foods? Show changes you would make and give reasons for so doing.
4. Make a list of all foods you have eaten in the last 24 hours that contain vitamins. Refer to tables on pages 326 to 327. How could you improve your dietary?

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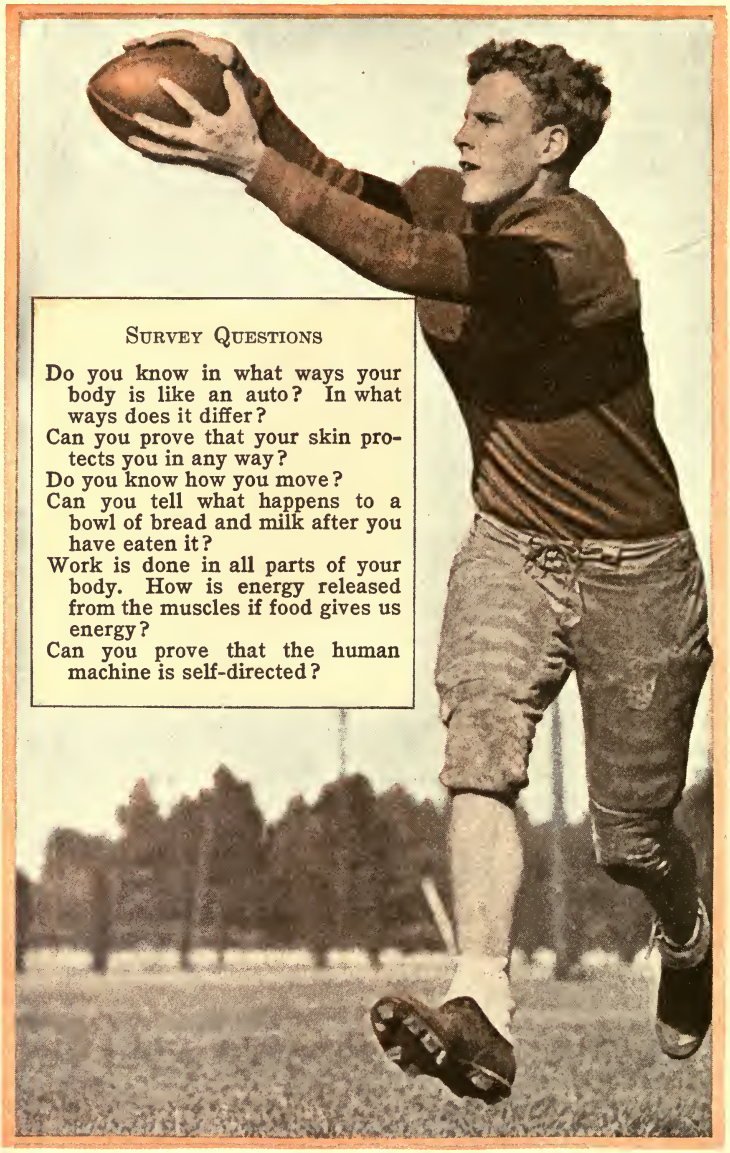


Survey Questions

Do you know in what ways your body is like an auto? In what ways does it differ?

Can you prove that your skin protects you in any way?

Do you know how you move?

Can you tell what happens to a bowl of bread and milk after you have eaten it?

Work is done in all parts of your body. How is energy released from the muscles if food gives us energy?

Can you prove that the human machine is self-directed?

Carroll Photo Service

UNIT XII

THE HUMAN MACHINE AND HOW TO CARE FOR IT

PREVIEW

Each of you has seen a modern locomotive pull a heavy train up a grade and has wondered at the work it does. Who has not marveled at the efficient running of an auto or an airplane engine? But each boy or girl who reads these lines controls a more wonderful machine than those just mentioned. Think of it for a moment — a self-regulated, intelligent machine which does many kinds of work, which repairs itself when it is injured, and which, if taken proper care of, will long outlast the locomotive or auto. And yet we think little about its care and often abuse it. When a navy battleship or destroyer is to make a test run, the fuel is selected with the greatest care. Every one knows that an auto engine requires constant lubrication and a good quality of gasoline if it is to do its work effectively. But how many boys and girls think very much about what is the best fuel food for their own machine, or what to do to keep the machine in good running order?

We say that the human body is like an engine or an automobile, but can we prove this statement? What is a machine anyhow? You have all seen the fireman shoveling coal into the fire box of a locomotive engine or have watched the man at the gas station fill the fuel tank of your automobile. But have you ever stopped to think of what happened to that fuel after it burned? That fuel

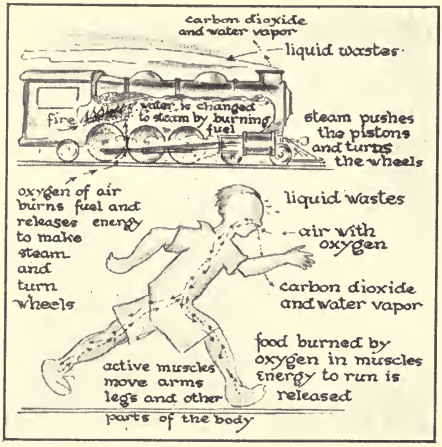
Wright Pierce

Where does the energy come from which pulls this heavy train up the grade? Is the engine getting full efficiency from the fuel? How do you know?

contained power or energy which was released as it burned. Then this energy pushed the piston of the locomotive engine and turned its wheels. In the auto engine the gasoline exploded in the cylinders of the engine and drove pistons which turned a shaft and transmitted the power to the wheels. In both cases the power or energy locked up in the fuel was let out in the process of burning or oxidation, and this energy was transformed into work done by the driving wheels.

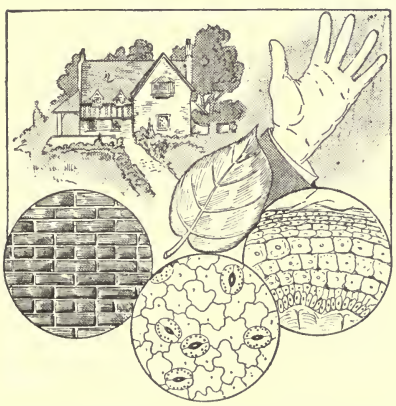
The human machine works in much the same way. Most foods, as we know, are fuels. When taken into the body, they are actually burned or oxidized and give up their energy. This energy is then transformed in the human machine and causes work to be done. That this is actually so can be proved by some simple demonstrations

which we shall see later. The human machine, however, does more than do work. Unlike the auto or the locomotive, with proper care, it can grow larger and stronger or with abuse, it can waste away, become weaker, or even die. The food it consumes is not all fuel, for the human machine grows and is to some extent regulated by foods which, as we have seen in a previous unit, are not used as fuels. In this respect the human machine is very different from the man-made auto or locomotive.



Explain this cartoon in your workbook.

In order to grow, that is, gain in weight and size, the body uses the various chemical elements in the foods, building them into complex combinations which make up the living matter of the body. This living matter is built up of millions of tiny units called *cells*. You have all noticed that a brick building when seen from a distance does not show the individual bricks. So in the human body we cannot see these tiny



Just as this house is made of bricks, so the plants and our bodies are made of cells, the units of structure in living things. Can you see the cells in your body?

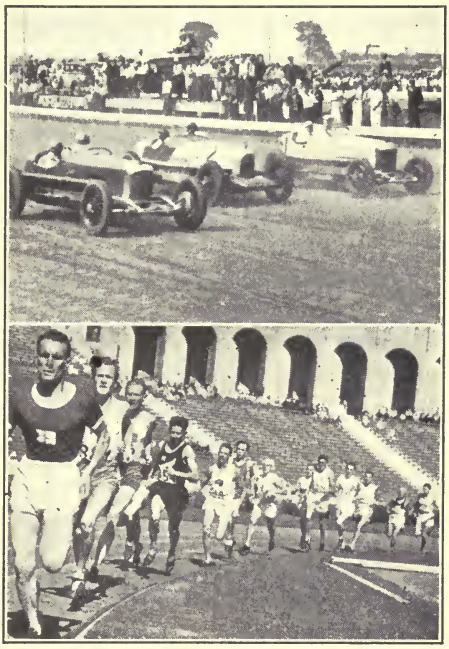
units or cells unless we use a microscope. Food helps to build these cells, and in a growing boy or girl the number of cells is constantly increasing. Food also gives off energy when it is oxidized or burned in the body. Each kind of cell, muscle, bone, or nerve has its work to do. This work means expenditure of energy — the energy we get from our food which is distributed to the cells by means of the blood. There in the cells, and there only, the food is actually oxidized, and gives off energy in the form of heat, to do our work.

But you ask, how can pieces of solid food get into these tiny cells? Food is of no value to the body until it does get into the cells, and to do this it must be in the form of a liquid. This is done by a process we call digestion, during which food changed from a solid to a liquid form. In this condition it may be absorbed or taken up by the blood, then circulated to various parts of the body. Finally, it enters the cells or individual units of the body, where it is actually used. The pages which follow will help us understand a little more about the care of this most wonderful of all machines, the human body.

PROBLEM I. HOW DOES THE HUMAN MACHINE DIFFER FROM AN AUTOMOBILE?

How an Automobile and the Human Machine Are Alike. At first sight the human body does not seem much like an automobile and yet we can see many ways in which they are alike. Both have a framework which holds them up — in the auto it is metal, in the body, the bony skeleton. Both have protective coverings, the glossy paint finish in the auto, the skin in the body. Both consume fuel and use it in the same way to release energy or power to do work. The gears and wheels transmit the power in the automobile, while in the human machine

a complicated system of bony *levers*[1] worked by muscles gives us our ability to move about. We might even compare the system of pipes which carries the fuel in the auto to the system of blood vessels which carries food to the parts of the body where it is used or the electric wires of the car to the nerves which carry messages to various parts of the body. Both engine and body must get rid of the waste material, for no engine can run with its fire box clogged with ashes, nor can any human being live long without getting rid of wastes. Neither engine nor body can be overworked without breaking down. Rest has been found to be necessary for metals as well as for man. It is necessary to allow the most smooth-running machine to take a rest now and then if the machinery is to be kept in good condition.



Wide World

Compare these two kinds of machines. List the likeness and differences for your workbook.

How the Auto and the Human Machine Differ. But let us ask ourselves, how do these two machines differ? Several differences are easily seen. In the first place the automobile, once made, can never grow, while we know the human machine, if properly cared for, can grow larger,

[1] *Lever.* A bar capable of turning around one point.

using the food taken into the body to do this. We also know the auto cannot repair itself if injured, while our bodies if cut or bruised will soon heal if we are in good condition. And perhaps most important of all, while the auto has to be directed from the outside, the human machine is self-directed. And each human machine is an individual, alike in general pattern to every other, yet different. Anyone of us may accomplish great things if we have our machine in perfect condition, or we may be handicapped throughout life by not knowing how to get the most out of it.

The Building Materials of the Human Machine. We have already learned that plants and animals are made up of living units of living stuff called *cells*. The human machine is also built of these tiny bits of living matter. They are so tiny that it would take several thousand to fill the space made by this letter O.

Demonstration 1. Body Cells.

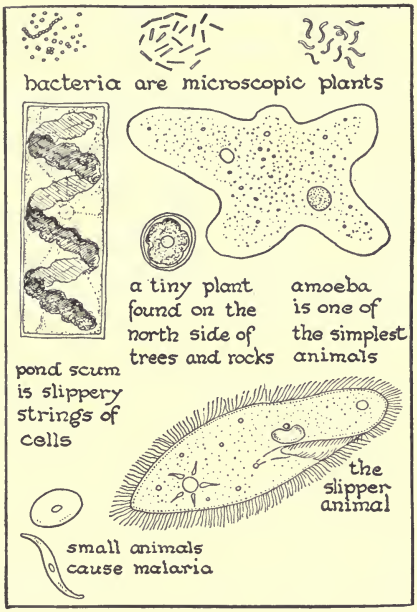
Scrape the inner surface of the mouth with a clean spoon. Wash off the scraping, on a glass slide, with a drop of water, add a drop of blue ink and examine under a compound microscope. The structures seen are cells which make up the inner lining of the mouth.

Every cell has a body made of living matter, while within it is found a darker staining structure called the *nucleus*. We shall find in our later study of biology that the nucleus has a very important work in the division of cells. As the body grows, the cells of which it is composed are constantly dividing to form more cells, so that our bodies are formed by the multiplication of cells. These cells do not grow in size, but in number, and it often happens that a very large animal or plant is made up of small cells, while a tiny one may be made up of very large cells.

Demonstration 2. Cells in Hay Infusion.

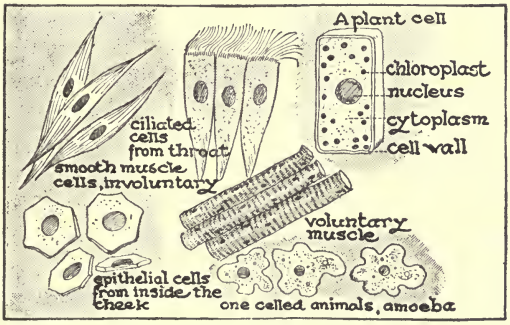
Place a drop of a hay infusion under the low power and see how many different kinds of cells you can find.

Some Cells Can Live Alone. There are many cells which can live by themselves. We have heard of the bacteria — they are such forms of life. Pond water swarms with many different kinds of single-celled animals and plants, while in some parts of the ocean they are so numerous that they form the food of other larger animals.



Some cells that live alone. The plant at the left is a string of cells and is magnified much less than the rest of the plate. All of the plants and animals shown live in the water.

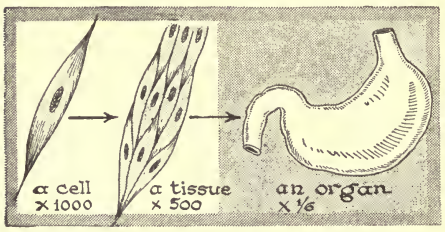
Cells Form Tissues. But although cells all have a similar structure, they differ greatly in size, shape, and use in the human body. We have blood cells, muscle cells, bone cells, nerve cells, and many other varieties. These cells, when they are all alike and all doing a certain kind of work, are called *tissues.*



Cells from tissues.

Tissues Form Organs. We also find in the body that groups of tissues may have some work to do together. Take,

for example, the hand. It is made up of skin, bones, muscles, nerves, and other tissues. But these tissues all work together. We call such groups of tissues an *organ* and the different plants and animals are called *organisms* because they are made up of numerous organs.



Tissues build organs.

The Human Machine an Organism. In man, the most complicated of all machines, we find many systems of organs. We find the protective covering or skin, beneath it a layer of fat, then muscles giving form to the body and by attachment to the bones allowing movement. We also find a tube running through the body, made up of many kinds of cells, and varying greatly in structure. Since it has a general work to do, we speak of it as the digestive tract, for its job is to make food usable in the body by digestion. Other systems of organs are found. We know the use of the lungs in breathing and of the heart in pumping the blood over the body. Most wonderful of all is the directive apparatus called the nervous system. By this complicated group of organs, those of sight, hearing, smelling, tasting, and touching, we are able to know about things which surround us. And by means of the nerves, which connect these organs of sensation with the directive apparatus called the brain, our human machine is able to run intelligently.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

skeleton	nonliving	heavy	steam
protective	tissues	organs	food
oxygen	nitrogen	carbon	hydrogen
self	protection	build	energy
blood	cells	tear down	oxidize
repair	wastes	living	dead

The auto and the human body are alike because they both release (1)____ when they (2)____ fuels. They both have (3)____ coverings, both have a framework or (4)____, both use (5)____ to release energy, both have to get rid of their (6)____. But they differ greatly because the human machine can (7)____ and (8)____ its structure out of (9)____, and it is (10)____ directed. It is made of (11)____ material the units of which are called (12)____, while the auto is made from many (13)____ materials.

STORY TEST

SALLIE TELLS ABOUT CELLS

Read carefully and critically. List all the errors and suggest corrections.

My teacher has asked me to tell the class what cells are and what they do. Your body and mine are made of cells. They are tiny units of living stuff so small that single cells cannot be seen except with a microscope. Like bricks, they are all exactly alike in size and shape, the only difference being that big animals and plants have big cells while small ones have little cells. As a body grows larger, the cells grow in size, so this is another reason why larger things have larger cells. Every cell has a nucleus and grows by dividing, so that one cell may form two, these two, four, and so on. This is all I know about cells.

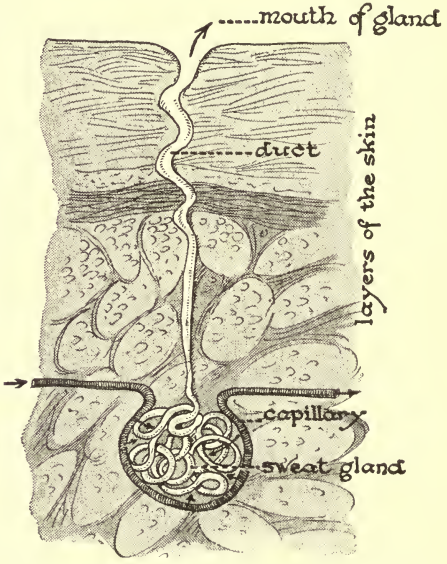
PROBLEM II. HOW IS THE HUMAN MACHINE PROTECTED?

The Skin, Its Uses and Its Care. We all know that the skin is a protective covering and that if we cut or break it, we feel a sensation of pain. The figure on page 361 shows us that the skin is made up of cells, the outer layer of which is largely dead, while the inner layer is very much alive. It is this part that bleeds when we scratch or cut ourselves, for it is really supplied with tiny blood vessels. If you look at the surface of the skin on your

hand, you will notice that it is thrown into many tiny ridges. These have no particular pattern and they are so individual in different persons that finger prints made by pressing these ridges on an ink pad and then on paper are used for purposes of identification, for each person's finger prints are different from each other person's.

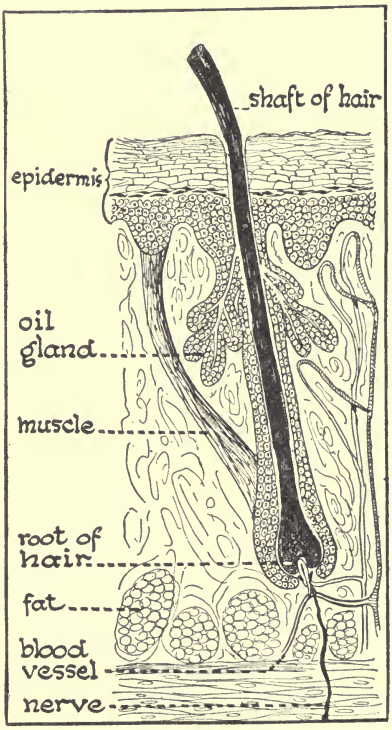
Finger prints of the same area in three different persons.

If you could examine a bit of your skin with a microscope, you might find many tiny holes which open on its surface. These are the openings of the *sweat glands*, tiny groups of cells which take water and wastes from the blood. We perspire when we are warm, and, as a matter of fact, the water which passes out not only carries wastes from the blood, but also gets rid of some heat. Since these tiny pores are very important in the regulation of our body temperature, we must not allow them to become clogged with dirt or grease. The frequent use of soap and water is necessary, especially after working in a dusty or grimy place, if we are to keep the pores open.



A sweat gland showing its position in the skin. Can you find the outer dead layer? Wastes are passed out through the mouth of the gland.

Hairs and How They Grow. Have you ever looked at the back of your hand when it was held in a strong light? If so, you noticed many hairs growing there. Although these hairs are thicker or longer in some parts of the body, we can find them growing almost everywhere from the skin. They grow as the accompanying diagram shows, from little pits in the *dermis*, or inner skin. At the base of each hair are found tiny collections of cells which form oil called oil glands. These lubricate the hairs. Since the openings of these glands may become clogged with dirt, surfaces covered with hair should be washed frequently.



A section cut through a hair. In which layer of the skin do hairs grow?

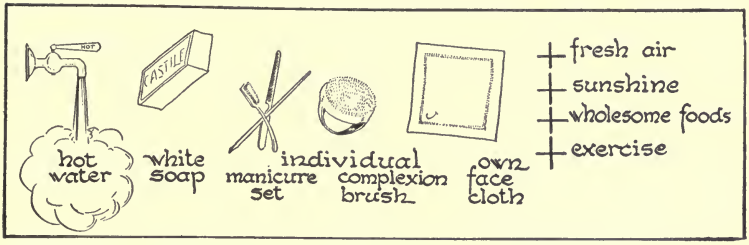
Care of the Hair. The simplest method of caring for the hair is brushing. Whether the hair is long or short, both boys and girls should brush their hair thoroughly every day. This keeps the scalp stimulated and free from dirt or dandruff. It also distributes the natural oil from the scalp over the length of the hair and makes it look glossy and healthy. Wetting the hair with water every day to keep it in place is a bad habit, which has often been blamed for early baldness. Unruly hair may be trained into place by the use of a light oily dressing.

Sticky or waxy fixatives should be avoided because they may harden into a thin coating all over the scalp, which stunts the growth of the hair.

Hair should be shampooed as often as it needs it. The average time is once every two weeks. Pure Castile soap is the best for shampooing. All strongly alkaline substances, like laundry soap or washing powders, should be avoided. Where the water is hard, it can be softened with a little borax or soda, dissolved in the water before soap is used. The scum that often forms on the hair when it is washed in hard water can be removed by careful rinsing with a little lemon juice or vinegar (also to be added to the water, never poured directly on the hair). Both water softeners and acid rinses must be used sparingly, because they make the hair reddish, harsh, dry, and brittle. Hair that is burned or dried from the sun, salt-water bathing, or any other cause can be improved by treatments with a mixture of olive and castor oils.

Care of the Nails. The nails on the fingers and toes, like the hair, and like the feathers, scales, horns, and hoofs on lower animals, are outgrowths from the inner skin. Normally they grow continuously, and if one falls out or is injured, another comes to take its place. Young people should learn to care for their nails as carefully as they wash their hands. The skin at the base should be pushed back regularly, and the nails should be kept clean under their free edge by means of a blunt, soft stick. Metal instruments may injure or disfigure the nails. They should be well shaped with a thin file, and, above all, should never be bitten off, because biting causes changes in form and growth which can never be corrected throughout life. Many a man and woman have regretted in later years the bad habit of biting the nails in childhood.

Care of the Skin. No other part of the human machine needs care more than the skin. In the first place it should



What are the best ways of taking care of the skin?

be kept clean, especially the face and hands, for they are exposed to dirt, smoke, and other irritating substances. Nothing is better for cleaning than plain soap and water. Scented soaps, powders, or lotions do not improve the skin and often do harm by clogging up the pores or placing substances that are injurious in the skin. The tubes from the sweat and oil glands are readily filled with dirt or other substances, and if certain bacteria lodge in these ducts, they are apt to cause pimples or boils. In severe or chronic cases of this kind, the boy or girl should go to a physician for advice and treatment. Careless or incorrect treatment often causes marks in the skin, which may remain as permanent disfigurements.

If the skin becomes sunburned, it should be protected from further injury by the application of soothing ointments and lotions. Frequent exposure gradually makes the skin tough, and freckles or tan may develop. The best thing to do for these discolorations is to let them wear away, because skin bleaches have little or no beneficial effect.

The Use of Cosmetics. Young skin has normally invisible pores and a healthy glow from the lively circulation in a well-exercised body. "The key-note of beauty is naturalness," so the natural color in her cheeks and lips should make artificial aids to beauty unnecessary for the young high school girl. But she must keep her skin

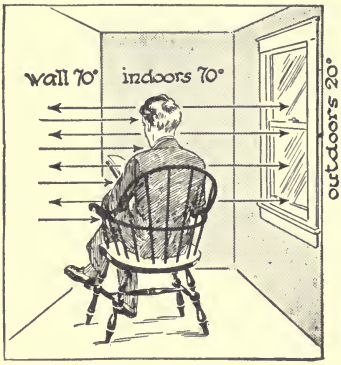
perfectly clean. Oily skin needs only mild soap and water, but dry skin can be improved by the use of a good cleansing cream (preferably one containing a little lanolin or other animal fat) after washing.

There is no such thing as a "skin food" beyond what is taken into the mouth as food for the whole body. Remember a healthy skin is a natural skin.

The Skin Regulates Our Body Temperature. We are all aware of the fact that sometimes we feel hot or feel cold, but if we were to take the body temperature at either of these times, we would find it varied little from its normal heat of 98.6°. To be sure, the outer part of the skin would be colder on a cold day and warmer on a warm day, but the skin itself has a very complex mechanism for regulating our body temperature. By means of the sweat glands shown in the diagram on page 360 as little coiled tubes, and the very delicate nervous apparatus which controls the amount of sweat released, the skin is enabled to regulate the heat of the body. When we do more work and the body becomes warmer from the increased oxidation within it, the skin automatically is enabled to throw off this heat and it is able also to retain more heat on a cold day.

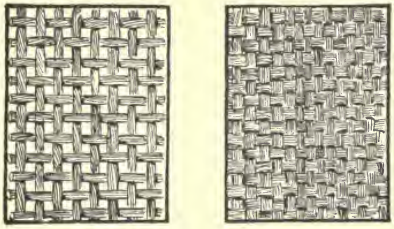
How the Body Loses Heat. Heat is lost from the body by the three methods we have studied in the preceding chapters. A certain amount of heat is lost by conduction, although the air is a very poor conductor, and warm fabrics get much of their heat-holding qualities because of the stagnant air confined in their meshes. Most of our heat from the body is lost by convection. When we fan ourselves, we create a current of air, causing cooler air to replace the warm air about the body. We also lose heat by radiation to other solid objects which are cold. It is very easy to take cold by sitting on the damp ground, or close to cold windows or walls, because in this way

warmth is removed rapidly from one part of the body. Curiously enough, although we feel warm when we perspire, much of the heat of the body is taken away by evaporation of the water from the body surface. On a hot muggy day, when the atmosphere is moist, little heat is lost by evaporation and we feel much hotter than on an equally hot, dry day when we perspire freely. On a humid day a blanket of stagnant heated air forms about the body, which makes one feel very uncomfortable. For this reason electric fans have saved people from much discomfort by keeping the air in motion, thus evaporating the moisture and removing heat from the body.



Study this diagram carefully. What important story does it tell about the loss of heat from your body?

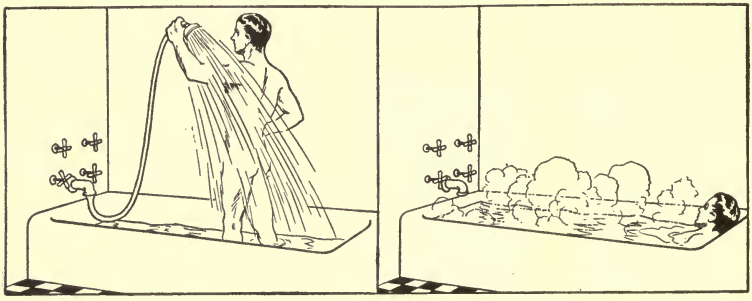
Underclothes and Their Uses. In winter we need underclothes which are nonconductors of heat, and retain the warmth of the body. In summer we need underclothes that do not hold moisture, for wet, clammy underclothes cool us by conduction if it is cold, or if it is warm, make us uncomfortably hot by preventing evaporation, and sometimes even cause a cold to develop. It does not seem to make very much difference what kind of materials are used, whether woolen, cotton, linen, or silk fiber, so long as the underclothes are porous.



Which weave of underclothes will be better for summer? Why?

Woolen underclothes are best for wear in winter, because the natural curly fiber makes them porous, and also because they absorb more water, and this protects the skin from cooling too rapidly in case we get overheated. Most colds are taken because people insist on wearing too much in winter. They wear heavy underclothes and heavy outer clothes, then go from a warm room to the cold outdoors, and back again to warm workrooms where the temperature is often higher than that of summer heat. The better rule is to wear a medium-weight underwear in winter and heavier outside clothes, which can be changed as one goes into different temperatures.

Bathing and the Skin. Since the skin is such an important organ for heat regulation and for getting rid of wastes as well, it goes without saying that we should take good care of it. Bathing keeps the pores open and the skin clean. In summer, when perspiration is increased, baths should be more frequent than in winter. A cold shower or plunge every day, both in winter and in summer, is an excellent habit to accustom the skin to different changes. If you find that after a rubdown the skin does not glow and you feel cold and chilly, do not take the baths so cold. It is always well to begin with tepid water and gradually turn on colder as the bath progresses.



Which bath should be taken in the morning and which in the evening? Give your reasons.

Hot baths should only be taken at night, as they tend to bring blood to the skin and increase the radiation from the body, thus making the chances of taking cold greater. But hot baths take the blood away from the brain, thus helping anyone who is wide awake to get to sleep more easily. The best bath is the shower, for this stimulates the outside skin, helping to make it resistant against colds. When we chill the body, the body resistance is lowered and germs, which are almost always present in our mouths and throats, develop rapidly and cause a cold.

Habits of Cleanliness. "Cleanliness is next to godliness" is an old saying, and a good one. Habits of cleanliness at meals are particularly necessary. One should always wash the hands after going to the toilet. Bathing the entire body at least once a week should be a habit, and if the feet or body become covered with perspiration in warm weather, one should bathe every day.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

raise	dead	oil	ridges
hairs	sight	protected	temperature
depressions	different	pores	identification
touch	nerves	hearing	blood vessels
alike	prints	bones	cells
sweat	alive	regulate	arteries

The human machine is (1)____ by the skin. It has two layers, the inner of which is (2)____. It is supplied with (3)____ and (4)____. It gives us sensations of (5)____, (6)____, and pressure. Nails and (7)____ grow from the inner skin. The skin has millions of (8)____, which are openings of (9)____ glands. The skin in giving off perspiration helps to (10)____ our body temperature. Due to the fact that the skin is thrown into (11)____ and (12)____ and that the skin of every person is slightly (13)____ from that of every other person, (14)____ are made of the finger tips and are used for purposes of (15)____.

STORY TEST

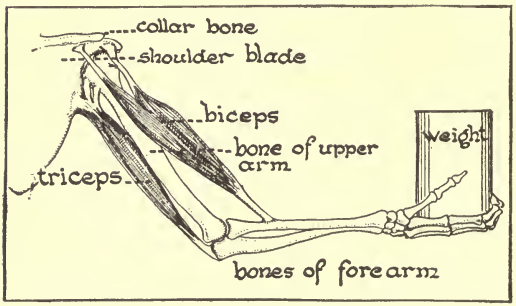
AGNES TELLS HOW TO TAKE CARE OF THE SKIN

Read carefully and critically. List all the errors and suggest corrections.

Every girl likes to have a good complexion. Most people think that unscented soap and water are best, but I like to use scented soap and face powder. The powder keeps dirt out of the pores and gives color to the skin. A touch of rouge is also attractive and makes the skin healthy, because it also keeps dirt out of the pores. The hair can be kept in good condition by frequent brushing as this spreads the oil from the glands at base of the hair over the surface of the hair. It is not good to allow cold water to touch the skin as this is apt to chill it and then we take cold.

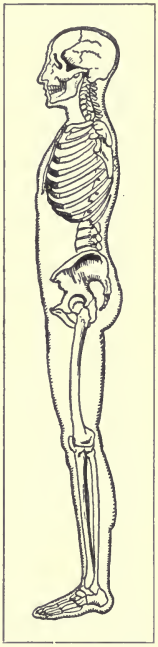
PROBLEM III. HOW DOES THE BODY MOVE?

The Skeleton and Muscles. Have you ever thought of what the skeleton does for your body? You may have seen a jellyfish or some other animal that has no skeleton either inside or outside of its body. A jellyfish thrown up on the beach has no definite form. It is only when the water supports it that it has its beautiful shape. Without a skeleton our bodies would sink into a shapeless mass, for we are over 65 per cent water. The skeleton gives attachment to the muscles, thus aiding in movement. Study the diagram on page 369 carefully. You will notice that instead of being all in one piece, the skeleton is made of many bones and that those used for movement are jointed. The skeleton protects the delicate parts of



Why can the arm lift a weight? Read through the entire problem before you attempt an answer.

the body. Look at the bony skull which protects the brain, and notice how well it is fitted to do this. Observe in the accompanying diagram how the curved ribs are attached in back to the backbone and in front to the breastbone, thus forming a protection for the delicate lungs and other organs held in the cavity they surround.



Does the skeleton give shape to the body? What other functions has it?

What Are Bones Made of? If you burn one leg bone of a chicken in a hot fire, it can be reduced to a little heap of white ashes, largely lime. If the other leg bone is placed for a few days in a 10 per cent solution of hydrochloric acid, the mineral matter will be dissolved out so that the bone can be tied into a knot. Thus we see bone is made of animal matter as well as mineral. The bones of young people are growing and contain relatively more animal matter than do the bones of older people. A broken bone, therefore, is much more serious in an older person. Do you see why? Live bones are surrounded with a delicate covering of living matter, through which they absorb nourishment. Damage to this part of the bone is serious because it cuts off the food supply from the bone.

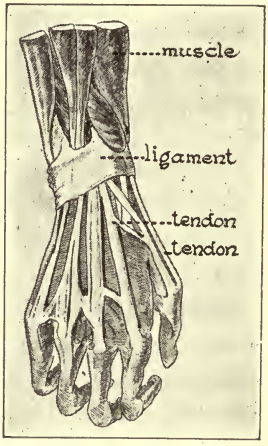
Bones and Muscles. How we admire an athlete! And how most of us enjoy playing games or swimming or hiking. Have you ever thought why the machine we call the body can do these things so well? Let us look at the diagram on page 368. The skeleton in a general way seems to have two purposes: one, protection; the other, to aid in movement. Move your own arm and you will see that the long bones are jointed. Now compare with the diagram and you will find the structures we call

muscles attached to the bones in such a way that when they lengthen or shorten, they raise or lower the bones, thus causing movement. Thus long bones act as levers, and allow us to move.

In what part of the skeleton do you think this fracture took place? Give your reasons after studying the cut on page 369.

Muscles are always found in pairs, so when one gets longer, the other contracts, thus causing movement. Find two such muscles in your own arm. Muscles are attached to the bones by strong cordlike tendons which are not so elastic as the muscles, but which serve to fasten the muscles firmly to the bones. Look at the leg bones of a dog or cat skeleton and you will find roughened places in the surface. These are where the tendons are attached. Now you can see what happens when you "pull a tendon" and why it is that you have to be inactive for so long after such an accident.

Ligaments and Bones. If you have ever tried to carve a duck, you may remember what a hard time you had disjointing the leg bones. As you cut into the joints, you found there white, glistening cords which held the bones together. These are the *ligaments*, and are found between all jointed bones. When we tear or injure a ligament, we have a "sprain." Sprains are often more serious

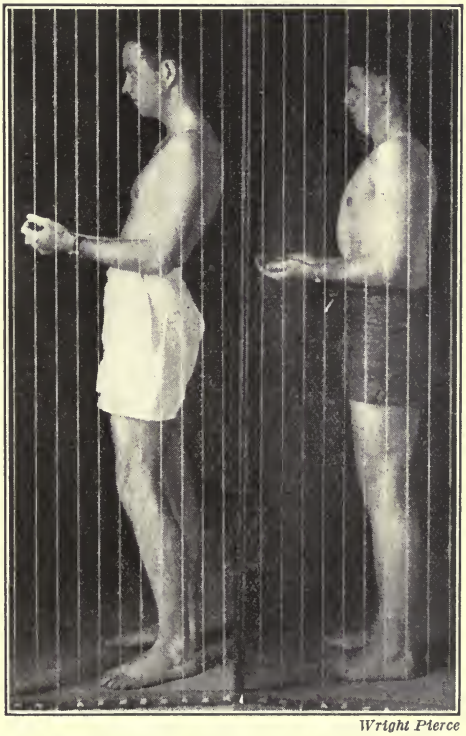


Notice how the tendons are attached to the muscles and are held near to the wrist bones by the annular or "round" ligament shown above.

than broken bones, for they heal slowly. Sprained joints should be bandaged carefully, have frequent hot applications, and should be rested until well.

Cartilage and Bones. If you have ever measured your height after getting out of bed in the morning, and again just before going to bed at night, you would be astonished to find that you had grown *shorter* during the day. But why? Your backbone is made up of a number of separate bones put together in the form of a double curve. Between each of these bones is a pad of elastic substance called *cartilage*. This protects us against jars when we walk or jump. You can thus see why the body is shorter at night. Cartilage is found between all movable bones and serves to make them more elastic, thus protecting them against breakage.

The Value of Good Posture. We all admire a boy or girl who stands erect and carries the body well. They look alert, strong, and graceful. It is said that more young people are turned down from jobs because of the bad impression given from poor posture than for

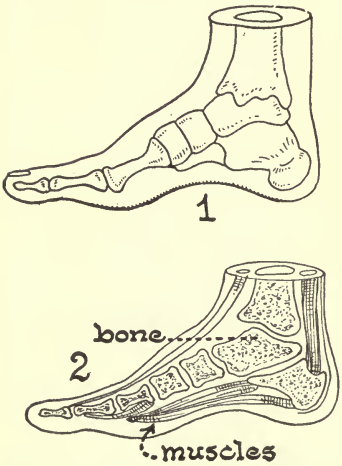


Wright Pierce

Examples of poor and fair posture in college boys.

any other reason. In good standing posture the body is held erect, the chest is thrust forward, and the head and shoulders are balanced above the body's center of gravity. A glance at the cuts on pages 369 and 371 shows that the skeleton, if held erect, balances the body so that no strain is put on any one set of muscles. Since good posture is largely a matter of habit, we should learn to achieve it while still young. In good posture the lungs, heart, and digestive organs are in proper position, thus aiding good breathing, circulation, and digestion. And most of all, we have a feeling of health which enables us to look at our tasks or difficulties and laugh them off because we feel well.

How to Get and Keep Good Posture. We first must have the feeling that comes with a knowledge of correct posture and then we must continually *practice* standing and walking correctly. If we fail to hold our head erect, or if we allow our shoulders to become round or let our chest slump in and our abdomen stick out, we are failing to practice good posture. Slumping over our desks when studying is one way to get poor posture and allowing the muscles of the abdomen to relax is another bad fault. Ask your physical education teacher to suggest exercises which will help you to build up a good erect carriage and then practice these regularly, for it is only by *constant* effort that we are able to keep good posture.



Notice how the muscles tend to keep the bones of the foot arched. What might cause the arches to fall?

Flat Feet. Fallen arches are often a cause of poor posture. Examine the diagram carefully. You will

notice that the bones of the foot form a perfect arch, which is supported by the pull of certain muscles and tendons of the foot. You can easily test your own arches by placing the feet in water and then walking on a dry, flat

Which of the two people have fallen arches?

surface. Fallen arches will make almost as wide a mark under the middle of the foot as at the toes or heel, while a good arch will only make a narrow mark under the middle of the foot. Fallen arches may give pain in the foot, the leg, or even the back. This is because of the strain put on muscles in order to keep erect. One of the best ways to keep the arches in good condition is to walk with the feet straight instead of "toeing out." If your arches are not perfect, ask your physical education teacher for exercises that will correct your trouble. Perhaps your shoes may not be correct. High heels often cause broken arches, as do shoes which are too narrow. Better be sensible than sorry!

Shoes for Comfort. For ordinary wear, heavy-soled shoes may keep the feet fairly dry, but in case of rain, it is better to wear rubbers, although most people consider them a nuisance. Our feet surely should receive our best care, for they bear our body weight the greater part of the working day. They are often harmed in youth by improper shoes, especially in the case of girls,

who pride themselves on the shapely appearance of the feet and ankles. The high heels worn by many do much to strain the muscles of the feet, and are responsible for many aches and pains in later life, which come as a result of flat feet, broken arches, and other ailments. Corns, callous spots, and blisters are caused by wearing shoes of a wrong size or shape for the feet.

This X-ray photograph shows how high heels throw the foot out of shape.

Shoes should be long and broad enough to give plenty of room for the toes. They should have a straight last, and the heels should not be too high. A common-sense shoe, sold by most dealers nowadays, is better than the longer, pointed, high-heeled shoe which is fashionable and worn by girls who do not realize the harm caused by wearing a shoe which does not fit the shape of the foot.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

living	protect	bony	levers
shape	trunk	contracts	unelastic
cord	triplets	pads	muscles
cartilage	mass	soft	unbalanced
support	string	organic	mineral
dead	ligaments	gravity	pairs
attach	balanced	expands	brain

The (1)____ skeleton helps (2)____ the body, gives it (3)____, and enables (4)____ to move the body because they are attached

to the bones which act as (5)____. Bones also (6)____ delicate organs such as the (7)____ and spinal (8)____. Bones are made of (9)____ as well as (10)____ matter. Muscles which cause movement are found in (11)____: one (12)____ when its opposite relaxes. Tendons (13)____ muscles to bones; (14)____ bind bones together. Between bones which move against each other are found (15)____ of elastic (16)____ which save the body from unnecessary jars. Good standing posture is brought about by having the head and shoulders (17)____ over the center of (18)____ of the body.

STORY TEST

JACK WRITES ABOUT POSTURE

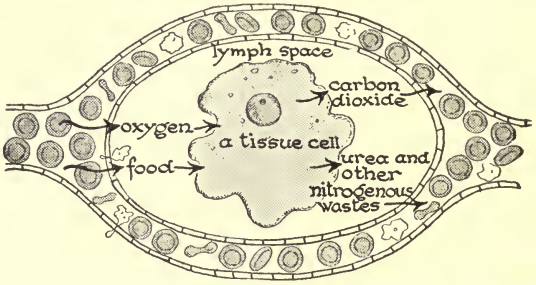
Read carefully and critically. List all the errors and suggest corrections.

Anyone who hopes to succeed in life needs good posture. Not only do employers like to see it in people who come to them for jobs, but it helps one keep well. Good posture can never become a matter of habit, you always have to practice it consciously. Postural exercises do not do us much good because if you practice them you get tired and that is bad. Fallen arches are a symptom of bad posture. You can test your arches by walking with wet bare feet on a flat surface. A wide mark made on the paper between toe and heel shows that the arch is perfect. Girls often wear shoes with high heels, which tip the body forward. This is often a cause of poor posture.

PROBLEM IV. HOW DOES THE HUMAN MACHINE MAKE USE OF FOOD?

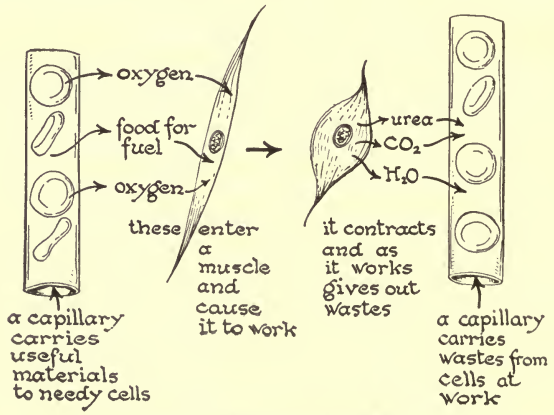
The Problem of Getting Food Where It Can Be Used. If we recall our auto, we remember that fuel is burned in the cylinders. The explosion of gas pushes the piston, which causes the shaft to revolve. This transmits power to the wheels and the car moves. Very different conditions exist, however, in the human machine. Food is not oxidized where it is taken into the body, but in the individual cells which do the work. If this is true, then while you are reading these words, work is done and food is oxidized in your hands, which hold the book, in the muscle cells which move your eyes, in the cells in the eye which register

the words you read, and in the cells of the brain which you use in thinking about what you read. Hundreds, perhaps thousands, of cells are involved in the simplest processes of daily life. So you see it is far from simple



How does food get to the cells? What happens to food in the cells?

to explain just how the human machine makes use of the food it takes in. Not only must the food be put into a condition so that it can get out of the digestive tract into the cells, but it must also be carried to these cells. In addition, if the food is to be oxidized, oxygen is used. This must get in from the air and be passed to the cells. Three systems of organs accomplish this work. First, the digestive tract prepares the food, or digests it, so that



How does a muscle work?

it may be absorbed into the blood. Then the heart must pump the blood and the blood vessels carry the food to the cells. In the cells, as the food is used, waste products are formed which must be removed and the blood must carry these away. A third system of organs brings the oxygen from outside the body so that it may get into the blood and then be carried to the cells. These are the organs of respiration, or the breathing organs.

These processes are all different, but each is tied up with the other. Food must be digested, then transported to the cells. Then oxygen must be used to burn the food before energy can be released and work done. In addition, some of the food may be used to build up the cells, and finally materials not usable must be removed — a complicated process, but if we take one thing at a time, we may be able to understand what happens.

Demonstration 3. What Do We Mean by Digestion?

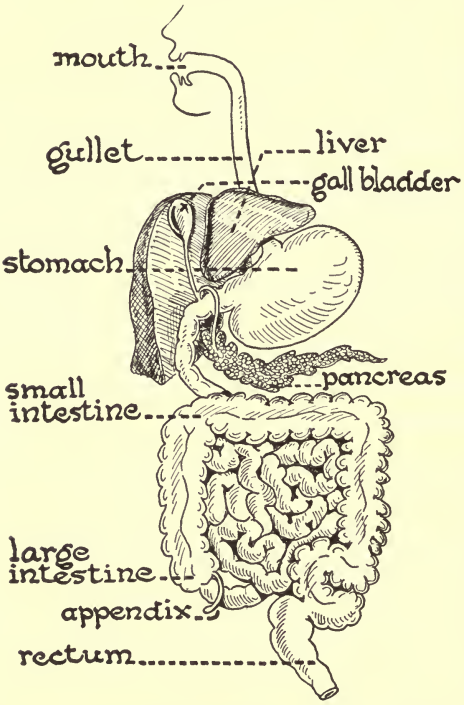
Place a piece of soda cracker in water in a test tube. Add a few drops of iodine. What happens? If the mixture turns blue-black, it shows the presence of starch.

Take another piece of the same cracker treated in the same way, but place in the test tube an equal amount of a blue substance called Fehling's solution. Heat to almost boiling. If the mixture in the test tube turns brick red, this shows the presence of grape sugar. What happens?

Now chew a piece of soda cracker until it tastes sweet. Continue to chew it until it is thoroughly mixed with saliva. Then place the chewed cracker with plenty of saliva in a test tube. Set the tube in warm water for 20 minutes. Then test the contents with Fehling's solution, treating as before. What happens?

This is an example of a controlled experiment by which we have proved that something in the saliva must have caused the cracker to change from starch to grape sugar. Starch will not dissolve in water, but sugar will. If food is to get into the cells, it must be in solution. These experiments show the necessity for digestion.

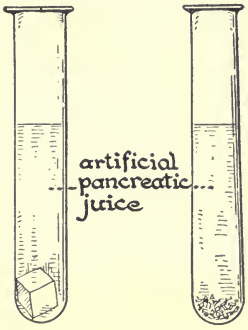
What Causes Digestion? We find in plants and animals that the process of changing foods from a solid to a liquid condition goes on rather constantly, for in no other way can food get into the cells. The process is brought about by substances which are called *enzymes*. These are the active substances in our digestive juices. In the mouth starches are digested by enzymes, while in the stomach proteins are changed to fluids by other kinds of enzymes. In the small intestine we have other enzymes that act on all three food substances: starches, fats, and proteins. We will learn more about these wonderful substances later.



The food tube of man with the liver and pancreas. What have these structures to do with the food tube? What is another name for everything shown in this cut?

Where Does Digestion Take Place? If you will look at the accompanying diagram, you will see the parts of the digestive tract of man. We have already seen that digestion takes place in various parts of the tract. The food, after being chewed and mixed with saliva, is squeezed down the tract by means of contractions of the muscles of the food tube. This movement occurs in both the large and small intestines and is of great importance in

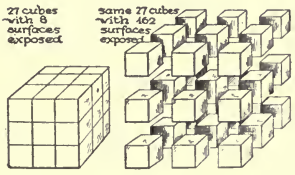
causing food to pass on its way. The food tube also helps to break up the food through the churning of its muscles. The end results are that the food which passes into the mouth in solid form is gradually broken up and then made soluble by means of enzymes formed in the glands in different parts of the food tube. The wall of the tube is filled with tiny blood vessels, and in the small intestine there are numerous tiny projections into which these tiny blood vessels pass. As the food becomes soluble, it is absorbed through these projections and gets into the blood and thus ultimately gets to the cells.



Demonstration 4. How Food Is Prepared for Digestion.

Cut a half-inch cube from a hard-boiled egg and place it in a test tube with a small amount of artificial pancreatic juice. Take a second cube of the same size and mince it. Place this in a second test tube with an equal amount of artificial pancreatic juice. Place the two test tubes in warm water and leave for half an hour. What has happened in each of the tubes? How do you explain this?

If enzymes are to do their work properly, then food must come in contact with them. If the food is chewed into small particles, a greater amount of surface will be exposed to the enzyme and digestion will then take place more rapidly. This shows the reason for chewing food. Our teeth are well fitted for this purpose; some are sharp and are used for cutting and others have broad surfaces used for grinding.



What is the object of chewing food?

Care of the Teeth. Thorough chewing of the food is necessary for good health. Many of us bolt our food, and as a result suffer

WILLIAM HARVEY, 1578–1657.

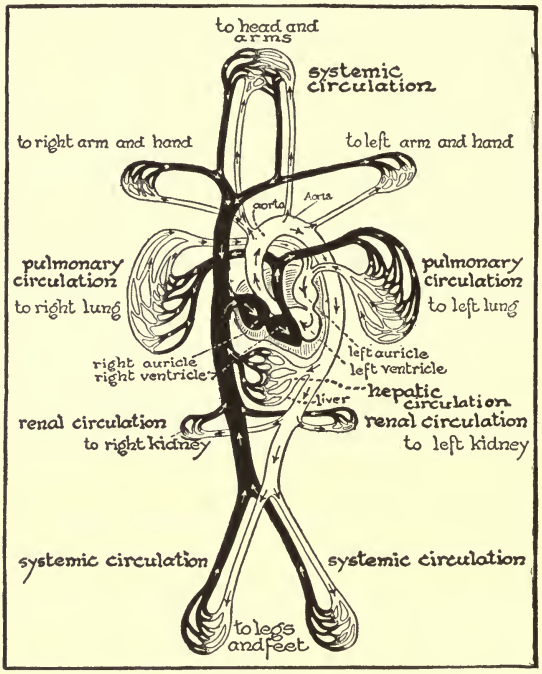
HARVEY as a boy must have led a pleasant life near London as a son in a well-to-do English family. At the age of fourteen he entered Cambridge University, and five years later went to Italy, where he studied at the University of Padua, under the famous anatomist, Fabricius. From him he learned of the presence of valves in the veins, a fact he made use of later. On his return to England he practiced medicine and taught in the medical school, and soon became one of the most noted physicians in England. He was the court physician under both James I and Charles I. But his name is remembered today for his discovery of the circulation of the blood. Up to this time physicians thought the blood moved in the body but did not know that the heart pumped it through the arteries. Harvey showed, in a book published in 1628, that there was a complete circulation from one side of the heart through the arteries and back through the veins to the other side of the heart. He never proved the existence of the capillaries, although he reasoned that they must be present.

We know very little of Harvey as a practitioner. In fact he was, according to some records, not at all popular. We do know he was an active physician and performed important surgical operations.

from indigestion. The teeth are important factors in the habit of proper chewing. We can form no better habit than that of properly brushing them. The teeth should be brushed at least twice a day, and not only the teeth, but also the gums around them. Brushing up and down rather than across the teeth is of much more value because it dislodges the food particles held between the teeth and thus prevents their decay. The teeth should be examined by a dentist at least twice a year, for this will save much pain and possible loss later on. Decay of the teeth comes as a result of bacteria lodging in the same crevices with food. They pour out an acid waste substance which attacks the hard enamel of the teeth, breaking it down and thus allowing germs gradually to attack the living portion of the teeth underneath. Upon our teeth depends much of our health later on in life, so let us form habits of proper care of them while we are boys and girls.

How Digested Food Gets to the Body Cells. We have already seen that the body is well supplied with blood vessels. If we could take away all flesh and bones from a body and fill the blood vessels with something that would hold them in place, they would form a perfect mold of the body, with tiny vessels reaching to all its parts. The fluid part of the blood is the vehicle which carries digested food to all parts of the body. Another solid part of the blood, called the *red corpuscles*, carries oxygen to the cells so that work can be done there. These red corpuscles are little flattened disks so numerous and small that it is estimated there are about 500,000,000 in a drop of healthy blood. We also find in the blood *colorless corpuscles*, the body police, which protect the body against harmful bacteria by eating them up. Other bodies called the blood platelets help the blood to clot when a blood vessel is cut, thus keeping us from bleeding to death.

What Causes the Blood to Circulate? But the blood does not just flow around in the vessels. It is under pressure from a double force pump we call the heart. This

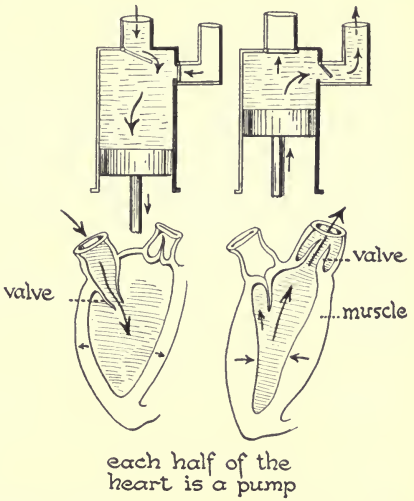


The blood circulates throughout the body by means of a continuous closed system of tubes, called the circulatory system.

organ, though not bigger than the fist of a good-sized man, pumps about a gallon of blood a minute, day in and day out, during our lives. When we exercise, the heart pumps faster, and during a game of handball or tennis it may pump five or six gallons a minute to the working cells.

Blood vessels which leave the heart are elastic with rather thick walls in order to withstand the pressure. These are called *arteries*. They are the vessels which pulsate as the heart beats and from them we get our pulse. Arteries branch out, getting smaller and smaller until

they form a network of tiny blood vessels which run close around the cells in the tissues all over the body. These small blood vessels are called *capillaries* and from the blood in them the cells get food and oxygen, and take up wastes. The capillaries in turn lead into tiny *veins*, thin-walled vessels which get larger and larger as they return blood to the heart. There are two complete circulations of blood in the body, one from the right side of the heart to the lungs, returning to the left side of the heart, from which it passes, as has just been described, to all parts of the body. The blood returns to the right side of the heart, thus completing the circulation.



The heart is a double force pump. Can you prove it from the diagram? The thick muscular part of the heart is called ventricle, the thin-walled upper portion auricle. Describe the heart's action, using the above terms.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

digested	lungs	stomach	cells
waste	carbon dioxide	oxidized	unites
liver	same	absorbed	bones
enzymes	energy	vitamins	fuel
kidneys	wasted	different	oxygen
used	soluble	blood	separates

Although the human body is like an engine, it differs from it in the way it uses its (1)____. All work is done in the (2)____ of the body. Food is (3)____ to release energy. Food must be made (4)____ or digested so that it can get into the cells. Digestion takes place in the food tube and is brought about by the action of substances called (5)____. Starches, fats, and proteins are each (6)____ by different (7)____. After the foods are digested, they are (8)____ into the blood, taken to the cells, and then (9)____ there. Oxygen from the air is taken into the (10)____ and from there carried by the (11)____ to the cells, where it (12)____ with the food substances and releases (13)____. The (14)____ products are carried away by the blood.

STORY TEST

PHILIP TELLS ABOUT AN EXPERIMENT

Read carefully and critically. List all the errors and suggest corrections.

We saw an experiment the other day that showed why we should chew food. The teacher took two pieces of hard-boiled egg exactly the same size. Then he chopped one piece up fine and left the other as it was and then put the two lots of egg into two test tubes. Each tube was about half full of some stuff he called artificial digestive juice. I think this juice contained an acid, for, after he left the tubes for half an hour in warm water, we looked again and found that the big piece of egg was not changed but the little pieces were all gone and the substance in one tube looked milky. I guessed that the acid dissolved the small pieces of egg. I don't see why it didn't break down the big piece of egg, unless it was because it wasn't strong enough.

PROBLEM V. HOW DO WE CONTROL THE HUMAN MACHINE?

How the Nervous System Works. You have all seen a race of sprinters. At the start all is attention. The runners get set. Every muscle is tense awaiting the starter's gun. Then off they go. What has happened? The boys in the race have been alert to listen for the sound of the starter's gun. Then the messages travel from the ear to the brain, and from there messages go to the muscles

Wright Pierce

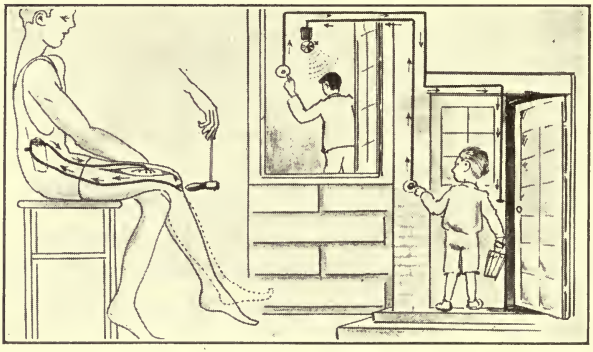
In a sprint the race usually depends upon the start. How did these boys get off "on the gun"?

of the legs and arms. Toes dig into the ground; muscles are tensed, and the boys are off. The nervous system has been the director and is responsible for their success or failure in the race.

The Central Nervous System. We know in a general way what the nervous system is. There are really two parts to the nervous system: a central portion consisting of the brain and spinal cord, which are protected by the bones of the skull and spinal column, and a number of paired nerves which leave the central nervous system and seem to run to all parts of the body. The nervous system is made up of cells like the rest of the body, but these cells are of various shapes and sizes and many of them have very long threadlike tails. These are the structures that make up the nerves. The nerves are made up of two kinds of cells. In one kind the cells pick up the sensation on the outside of the body by

sound or touch or smell and carry it to the inner nervous system. Here the sensory cells turn it over to another lot of nerve cells and they in turn translate the message to the muscles which act. Such nerves are called motor nerves. In every conscious act not one set of nerve cells but hundreds — perhaps thousands — take part. General science is not the place to study the details of the nervous system, but rather to learn something about its control and care. In our automobile we do not pretend to know much about the mechanics of the engine under the hood, but we want to know how to drive it carefully.

Unconscious activities are also controlled by the nervous system. When we sit in the driver's seat and decide where the car shall go, the engine goes purring along. Water circulates through the radiator, supplies of gas and oil are in circulation, spark plugs ignite the gas. All these activities go on if the car is to run. So in the human machine. As you read these words your breathing goes on, movements of the digestive organs take place, the making of enzymes, pumping of the heart, the regulation

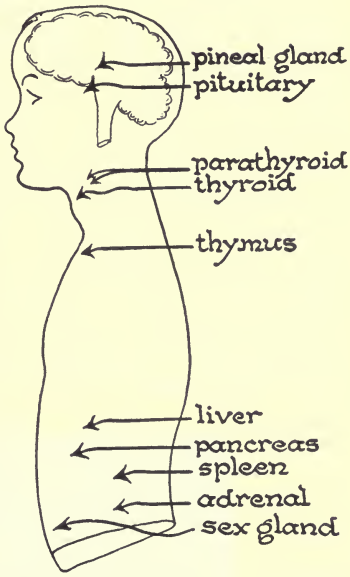


Two kinds of control are illustrated here. Read your text and then try to explain the picture.

of the body temperature — all are going on without any conscious activity on your part. The regular activities

of the body go on without our knowing much about what is taking place.

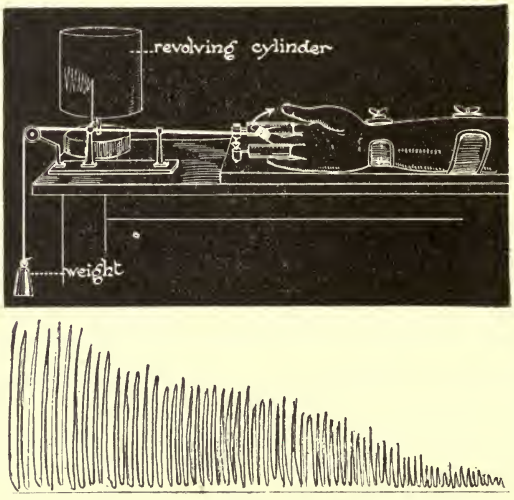
Two Kinds of Control. Your unconscious body control is of two sources. One is under the care of the so-called autonomic nervous system; but there is another control brought about by some very wonderful glands in the body. These glands are not connected with the food tube or other parts of the body, but instead pour their secretions directly into the blood. They are called *endocrine* glands. You have heard about some of them. The thyroid gland, for example, sends certain messages into the blood which causes a greater or lesser activity on the part of the body. The suprarenal glands are used at times when we are angry, or when we wish to make a desperate muscular effort of some sort. The pituitary gland, a little organ no larger than a chestnut, found at the base of the brain, controls the size of the human body. There are several of these glands which you will learn more about later in your study of biology, but they have a very definite effect on the running of the human machine. If they are in good condition, the human machine behaves normally. If they are out of condition, the machine may behave very badly.



Glands that influence body control. Can you tell what each one shown does for the body?

Other Things that Influence Body Control. You have all found that you could not work as well when you were

tired. This is due to the fact that the body cells, when they do work, give off poisons and these poisons gradually accumulate when we get overtired and cause the feeling of fatigue. No one can do his best work when he is fatigued. The nervous system is shocked by such poisons or by other poisons which we take into the body. One example would be tobacco. The effect of tobacco in general seems very slight. It may give you a smoker's cough, or it may seem to have no effect at all, but case experiments made with the same sets of men doing work with and without tobacco show that smoking makes for a loss of efficiency. The same is true with overdoses of alcohol. Here many other experiments where accuracy is needed — such as shooting at a mark or setting type — have shown that men without alcohol do much better work and more work than those who have alcohol.



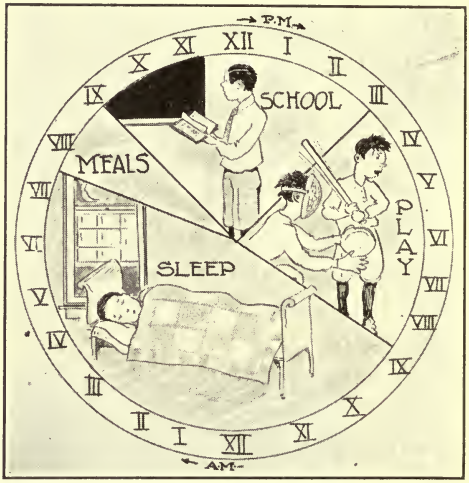
This apparatus is used to measure fatigue. As the finger is moved it lifts a weight and makes marks on the revolving drum. As the finger grows more and more fatigued the weight is lifted less distance at each effort and the marks grow shorter and shorter. At length the finger cannot be moved and no more marks are made. It has become too fatigued to do any more work.

Effective Running of the Human Machine a Matter of Training. No one would think of trying to drive a car in traffic unless he had learned first how to control it and then practiced in its control. So it is when running a human machine. Training and practice are necessary. You may remember Uncas the Indian. It was by training that he became acute enough to read the signs in the forests that told him that enemies or animals had passed that way. We learn in control by profiting by our mistakes. It is much more important in training that we know when we make a mistake and profit by it than it is to go on and luckily make no mistakes. We should learn to be alert and cool and, once having found the right way to act, to practice doing it so that it may become a habit. The boy or girl who has the habit of stopping to think before acting has done much to gain control of his or her nervous system. In reading or listening to any one, get the habit of paying attention to what is being said. A wandering mind is not an alert mind. By paying attention we avoid mistakes and avoid accidents. More fatal driving accidents come from carelessness than from any other cause. Above all, do your best all the time. "Not failure but low aim is crime."

What Is Fair Play to the Nervous System? Nerves can stand hard work for long periods of time, provided they get occasional rest and sleep. A transcontinental train cannot run a long distance without changing engines. This is done every 200 to 300 miles. In the human machine we must have occasional rest, and the best rest comes from sleep. Scientists say that children from eleven to twelve years of age should have from nine to ten hours of sleep. But even more important than long hours of sleep is the habit of taking short rest periods when tired. Learn to relax. When we go to sleep, we relax, as you can see if you watch a person who is just falling asleep

in an upright position. The head nods. This means that the muscles which hold the head relax and the head drops.

Exercise in moderation is also good for the nerves because it brings oxygen to the blood by causing the heart to pump faster and the lungs to take in more air. This gives the nerves opportunity to get more food and oxygen. But do not exercise when tired and do not exercise just before meals, for the blood then has work to do for the digestive tract. Many boys of junior-high-school age over-exercise in football practice. They are growing rapidly and their muscles are not yet ready for such strenuous exercise. Frequently the practice lasts until just before supper time, and they go to a meal feeling fatigued, with the result that they have indigestion.



Is this a fair allotment of time for a 7th grader? How does your own allotment agree with this?

Cheerfulness is another important habit for the nervous system. Look upon life from the bright side. If you grouch, it may become a habit, and this affects others as well as yourself. Learn to face problems fairly, not overestimating them or underestimating them. Never use drugs to deaden pain or stimulate the nervous system. Pain is the symptom of faulty running. If it continues, see a doctor. Do not let it continue to lessen the effectiveness of your machine.

Rest and Health. Our days should be made up of work and play, rest and sleep. It is just as bad to overexercise as it is to underexercise. One should remember that all machines need rest, and the human machine is no exception to the rule. At least eight hours of sleep should be had by every boy and girl of high school age, and nine or ten hours of sleep by younger children. Fewer movies and more quiet reading at home would be good for every boy and girl. Moderation in all things is a good rule. Overstrain of any kind brings on fatigue, and in the end shows that we cannot strain an organ without paying for it. If we overstrain the eyes, for example, we pay for it by wearing glasses later. If we overstrain in athletics, we may have to give up athletics altogether. Overfatigue by keeping too late hours will surely call us to account later in life. Let us learn while young the value of complete relaxation, and let us, while we are growing, get the habit of going to bed at the proper hour.

Fair play in running your own machine will result in your being well and happy and then you will feel like being fair to others.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

tendons	thinking	sheath
stimulations	blood vessels	autonomic
sense	muscles	outward
suprarenal	brain	control
endocrine	movements	thyroid
motor	breathing	inward
sensory	cord	nerves

The nervous system has the (1)____ of the human machine. There is a central part made up of the (2)____, spinal (3)____, outgoing (4)____, and another portion which consists of certain (5)____ organs like the eye or organs of taste, with nerves which lead

(6)____ and connect with the central system. The sensory nerves receive (7)____ while the outgoing nerves send messages to the (8)____ which result in (9)____. Hence they are called (10)____ nerves. In addition the ordinary automatic activities of the body such as (11)____, the beating of the heart, or the (12)____ of the intestines, are governed by the (13)____ nervous system. Certain glands called (14)____ also help control bodily activities. An example is the (15)____ gland, the secretions of which "pep" up the body.

STORY TEST

JANE WRITES ON HOW TO CONTROL THE NERVOUS SYSTEM

Read carefully and critically. List all errors and suggest corrections.

Each one of us has a pretty big job on his hands in learning how to control the human machine. Most of our daily acts are habit. So first he needs to learn to do things right and then make all of his thinking habits. He should aim high always. He should try not to be careless for that is habit also. Cheerfulness or grouchiness is habitual. But people cannot be habitually cheerful if they are in pain. Therefore, it is best to take something which will deaden pain if we have to, for in this way we can keep cheerful.

Like any machine, every so often the human body needs rest. The nervous system gets its rest through sleep. Never take short naps as this is wasted time. Long sleeping periods of from eleven to twelve hours at junior high school age is what we need.

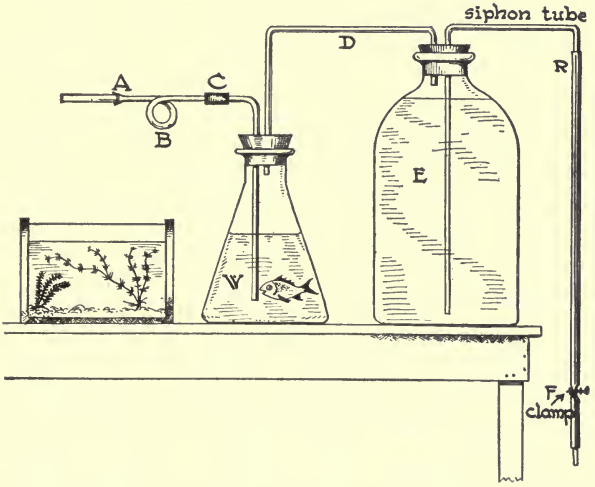
PROBLEM VI. ALCOHOL, NARCOTICS, AND THE HUMAN MACHINE

We Have Only One Human Machine. If you had a new car, you would not deliberately run it over the worst roads you could find, or allow dirt and dust to mar the fine finish. If you lived near the seashore, you would not deliberately run the car through a pool of salt water because you know that salt water would cause the exposed parts to rust. How much more important is the human machine and how much more careful we should be of it, for while we may be able to purchase a new car when the old one is worn out, our own body mechanism has to last us as long as we live. We should, therefore, try to use it as efficiently as possible and protect it from damage when we know how.

What Fatigue Poisons Do. You have all found out that you cannot work as well when you are tired. This is due to the fact that as we overuse the body cells, more and more waste products are formed and are not taken away as quickly as they should be. These wastes are poisons and as they accumulate in the body cells, they soon give us a feeling of fatigue. No one can do his best work when fatigued, and the fatigue poisons in time do great damage to the body cells. Especially is the nervous system damaged by poisons.

Demonstration 5. Effect of Cigarette Smoke upon Fish.

Prepare a cigarette smoker as follows: Heat the end of a glass tube and insert the end of a file and ream out the end, making it flaring so it will hold the end of a cigarette (*A*). Bend the tube to make a narrow loop. Connect the other end at *C* to a tube going nearly to the bottom of a Florence flask. Fill this flask just over half full of water and put a goldfish in it. Connect the



flask to a two-liter bottle (*E*) by means of tube *D*. Fill *E* with water and arrange tube to siphon water out of *E*. By opening clamp *F* and blowing into *A*, the siphon tube is easily filled. Close clamp. Insert cigarette at *A*. Open *F* and light the cigarette. As water runs out of *E*, smoke will bubble through the water *W*.

Not all the products of burning pass into the water. Notice matter collected in the coiled tube at *B*. After the fish shows the effects of the smoke, transfer it to a bowl of fresh water. Note the appearance and odor of the liquid at *B*. What becomes of this product when one smokes a cigarette?

What a Great Athletic Director Has to Say about Tobacco. The following letter which was sent by A. A. Stagg to a teacher in the Wellesley Junior High School, Wellesley, Mass., speaks for itself. Anyone who has followed his teams on the west coast knows that he is still a coach whose teams play the game as good sportsmen should.

The University of Chicago[1]
Department of Physical Culture and Athletics
Office of the Director

December 9, 1931

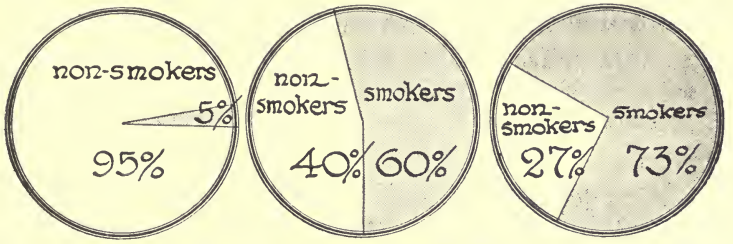
From personal observation of athletes who have been addicted to the use of tobacco, I can speak with confidence, that, as a rule, they do not possess the endurance of athletes who have grown up free from the use of it. Few people smoke without inhaling, which means that eight times as much of the nicotine poison goes into their systems, according to recent experiments by a German scientist, than from the use of tobacco without inhaling. One of the leading physicians of Chicago has personally told me that since he started smoking, his pulse has gone up ten to twelve beats, and another physician, to whom I told this, has confirmed it by his personal experience.

Outside of the matter of endurance, I have no exact data, but I am strongly of the opinion that athletes who have used tobacco would not have as steady nerves in tight pinches as non-users.

The Danger from the Narcotic Poison, Nicotine. Just as fatigue poisons damage the human machine so do other poisons damage it. You have often heard older people say when they were tired, that a good smoke rested them. It *seems* to rest them, for tobacco contains a narcotic poison called nicotine. Any narcotic deadens the senses and soothes a person into believing he is rested, but along with this comes the effect of the poison in the body.

[1] From *Manual for Teaching Effects of Alcohol, Stimulants and Narcotics upon the Human Body*. Commonwealth of Massachusetts, Department of Education.

While tobacco may not seem to do any great harm to smokers, it does harm people in the long run. One Russian investigator compelled certain rabbits to smoke



A study made at Yale University showed that 5 per cent of the honor men, 60 per cent of the average men, and 73 per cent of the failures were smokers.

cigarettes for periods of from 6 to 8 hours daily, with the result that some of the rabbits died within a month's time, showing heart changes. Others developed tolerance for tobacco like human smokers, but when they were killed, they showed degeneration of the blood vessels. Doctors who have made a study of the effect of tobacco on the human system find that cigarette smoking causes an increase in the heart rate and a heightened blood pressure which indicate the effect of the poison. The fact that heart trouble is increasing in this country makes us wonder if it has anything to do with the increase in the use of cigarettes which has taken place since women have taken up smoking.

Smokers Do Not Have as Good Chances at Athletics. While a smoker may not have smoker's cough or may not seem to show any loss of mental efficiency, yet studies of mental and physical efficiency indicate that the smoker is at a disadvantage. Certain statistics were gathered by a professor at the University of Utah in which he grouped students competing for places on the football teams in six institutions into groups of smokers and non-smokers. He found that only half as many smokers made the teams

as non-smokers, that the smokers showed a loss of lung capacity amounting to about 10 per cent as compared with the non-smokers, and in almost every case the non-smokers showed higher scholarship. Since there were over 200 men involved in this experiment, the figures ought to be worth something. Other experiments have shown that runners, especially distance runners, do not have as good chances of winning if they are smokers. Many coaches ask runners and football men to cut out smoking while in training because of the effect on their wind. An experiment by Professor Lombard of the University of Michigan showed that on days he smoked his muscles lost 41 per cent of their working power. So this looks as if the coaches were right.

Tobacco May Cause Serious Injury. One insurance company has figures based upon 180,000 policyholders which show that the abstinents from tobacco had almost twice as much likelihood of living to old age as those who smoked moderately all their lives. Dyspepsia, catarrhal

Wright Pierce

Successful football coaches forbid the use of alcohol and tobacco among the members of their teams. Why are such teams usually successful?

conditions of the nose and throat, and sleeplessness are some of the afflictions brought on by excessive smoking. Here are certainly enough reasons to show young people that the game isn't worth the candle.

What about the Harm Done by Alcohol? Anyone living in the world today knows the value of being alert and wide awake. No one who is interested in science would try to handicap himself at the start of life by dulling his mind and causing his muscles to lose their control. But that is exactly what the drinker does when he gets the alcohol habit. But you say: "If I drink, I'll know when to stop, and besides a little drinking never hurts any one." Science cannot agree with this statement. Alcohol is a narcotic drug and as such it is a habit-forming drug. In small quantities it may be used in the body much as an energy food is used, but unfortunately it has a narcotic effect as well. It seems to be able to deceive us by making us think we are stronger, more sensitive, and more efficient than we really are. It does this because of its narcotic or deadening effect. It is this fact about drinking alcohol that makes it so dangerous, for one soon becomes incapable of forming accurate judgment. He throws caution aside, takes chances, and makes errors. In an age when restraint and caution are needed in driving a car or crossing a crowded street, or doing the hundred and one things one has to do in a crowded city, it is evident that the drinker is at a decided disadvantage.

Alcohol Acts on the Nervous System. There is plenty of evidence that alcohol acting on the nervous system slows up the action of muscles, makes us react slower, and causes the loss of muscular control. You have doubtless noticed this effect in anyone under the influence of liquor. More than this, it blunts the ability to judge one's own actions, thus relaxing self-restraint and allowing one's emotions to rule his will or intellect.

Alcohol Damages the Body Machine. More serious still is the effect of alcohol upon the body machine. Alcohol taken in excess shortens life very considerably by undermining the structure of the digestive tract, liver, kidneys, blood vessels, and nerves. It slows muscular efficiency, as can be shown by experiments in mountain climbing, digging ditches, carrying weights, etc. In all of these experiments the subjects without alcohol did more work and did it better. It makes for inefficiency in any work where judgment and skill are involved, such as typing, drawing, or using machines. It slows up all mental work and makes it less accurate, although the person believes he is doing better work. No boy or girl who wants success in life can take a chance with alcohol.

SELF-TESTING EXERCISE

Select from the following list of words those which best fill the blank spaces below and arrange them in proper numerical order. A word may be used more than once.

smoker	nicotine	less	wealth
success	strong	heart	drinker
money	food	same	alcohol
body	failure	fatigue	athletics
health	scholarship	feet	narcotic
more	cells	machine	heavy
nervous	life	efficiency	light

When a person feels tired, it is because (1)____ poisons have been formed in the (2)____ of the (3)____. A (4)____ poison such as (5)____ which is found in tobacco acts in much the (6)____ way. Smoking is a bad habit because it not only wastes (7)____ but it also lowers one's (8)____. It does this through its effect on the (9)____ and (10)____ system. Smokers in college do not have as much chance in (11)____ or (12)____, according to statistics as do non-smokers, and their chances of good (13)____ are (14)____ than of non-smokers. The same may be said about the use of (15)____. Not only does it harm the human (16)____, but it handicaps the (17)____ so severely that his chances of (18)____ in life are not to be compared with those of the non-drinker.

STORY TEST

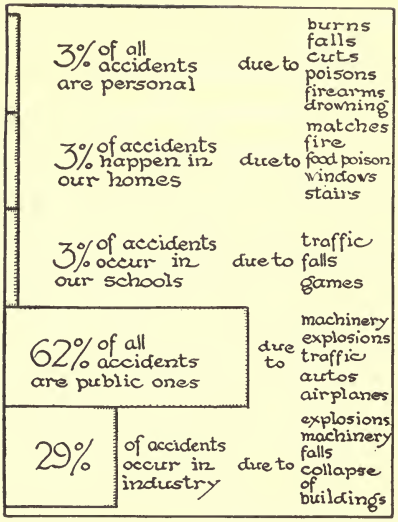
NED TELLS OF SOME DANGERS FROM SMOKING

Read carefully and critically. List errors and suggest corrections.

I used to think because my father smokes that I would, but I have changed my mind. In the first place, I tried it one day and it made me beastly sick. About this time we made an experiment in school. The teacher took one drop of nicotine which he got from an old pipe and stirred it up in a small bowl of water and then placed in it one of the goldfish from our school aquarium. It took just about five minutes to kill that fish. Well, that gave me a reason for being so sick after my first smoke. So I decided to investigate farther and do a little reading. I found that all tobacco contains nicotine and that it passes into the mouth with the smoke. Of course if you inhale, you carry some of it down into your lungs and that's just too bad, for sooner or later it poisons the tissues there. That I suppose accounts for the shortness of wind that the smoker often has. According to a number of experiments my teacher showed me, the smoker doesn't do as well in athletics or in scholarship as the non-smoker. And I also read that in Yale, I think it was, that non-smokers had smaller lung capacity than smokers, and were shorter and smaller. I got enough dope to make me feel certain that I don't care to try smoking now and I doubt if I will want to smoke when I get older, for it takes a lot of money that I could use to better advantage.

PROBLEM VII. WHAT IS THE IMPORTANCE OF SAFETY EDUCATION AND FIRST AID?

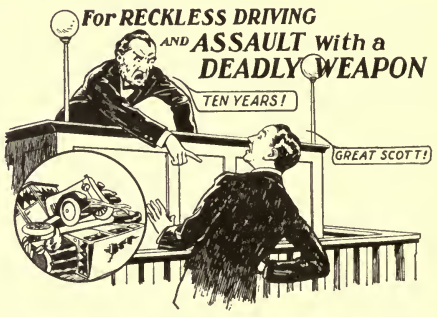
Why Safety Education Is Important. Did you know that last year over 34,000 people were killed in various traffic accidents; over 27,000 met their death in various industrial accidents; 13,000 more were killed by falls; and more than 6000 by burns and drowning? Over 90,000 people were killed, around 2,000,000 seriously injured, and no one knows how many slightly injured in one year. It is estimated that one out of every eleven of the 23,000,000 motor vehicles registered in this country is in an accident each year. In 1927, according to the United States mortality statistics, while there was a decrease in all other accidental deaths, in children of high



Classification of accidents in the United States.

school age between the years 1917 and 1927 there was an increase of nearly 17 per cent in the deaths from auto accidents and today conditions are worse.

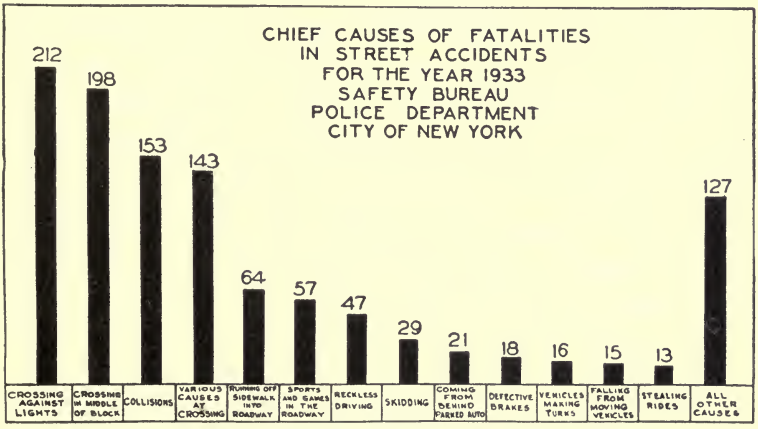
While the school cannot be expected to teach you to drive a car safely, it can point out some of the commonest forms of accidents and help you to avoid them. In 1933, in a total of 756,500 auto accidents in which the driver was at fault, it was found that over 575,300 people were killed and injured. The accidents that took the greatest toll of life and injury were in order these: (1) exceeding speed limit, (2) car did not have right of way, (3) car was on wrong side of road, (4) driving off roadway in traffic. Of the eleven listed accident causes, they constituted three quarters of all accidents. These then point out some definite things that young drivers should do. Most accidents occur at intersections. Always slow up and have your car under control. Carelessness at such places on the part of the driver is the biggest cause of accidents. Keep alert



If we had more verdicts like this we would have fewer reckless drivers.

and watch for what the other fellow may do. Do not speed; it is better to be safe than sorry. Brakes suddenly applied may mean a skid, a crash, and broken bones or worse. If you hope to drive without injuring others, you must drive carefully. Especially accidents are likely to come when young people cut in, fail to use hand signals, fail to stop at signals or a dangerous cross street. Nearly 10,000 people are killed or injured each year on grade crossings. It pays to stop, look, and listen.

What Are the Most Common Accidents to Pedestrians? It has been found that about one third of all pedestrian accidents occur at street crossings where there is no signal, about one quarter come from crossing between intersections, and about one fifth come from playing or riding bicycles in the street. This latter figure is increasing now that more boys and girls ride wheels. It is also found that "jaywalking" is responsible for a very large percentage of injuries. These facts show us the importance of watching our step while on the street. Playing games in the street, unless it is closed to traffic, is a risky occupation.



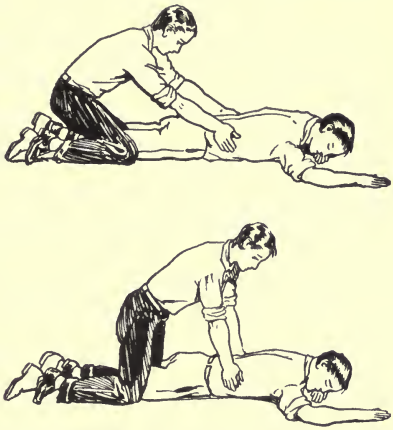
This is a typical graph. What can you do about it?

What Can We Do to Prevent Accidents? We can co-operate with city and state in observing traffic regulations. We can aid in the direction of the traffic near the schools by establishing traffic and patrol squads and by helping control traffic at times of congestion. We can organize safety campaigns and give personal demonstrations on how to behave safely and sanely. And, most of all, we can personally be careful, for by far the greatest number of accidents come through carelessness.

Have you a traffic squad in your school?

What to Do in Case of Accidents. In spite of everything, accidents do occur on the street, at school, and at home. Statistics show that in large high school systems — such as St. Louis and Los Angeles — the percentage of accidents based on their enrollment is over 1 per cent of the school population. Accidents happen in playing games, in the shops and laboratories, and on the school grounds. At home we have falls and burns taking a large toll. Suffocation and electric shock are frequent causes of death. Especially among high school boys and girls drowning accidents play a large part, over 30 per cent of all deaths coming from this cause. First and most important, we should keep cool. If the accident is serious, do what you can in first aid and send at once for a physician. A knowledge of first aid is important for every

boy and girl, and each one of us should know what to do in case of a bad cut, broken bones, or suffocation from drowning, fire, and other causes. The paragraphs that follow will help us to cut the toll of death from these accidents.



Read the text carefully and then explain the diagrams.

What to Do in Case of Drowning. In the case of drowning, electric shock, or poisoning by gas, the treatment is by artificial respiration. The prone-pressure method is easily learned and is generally used. In the case of apparent drowning, the first thing to do is to get the water out of the lungs and air passages. To do this raise the lower part of the body of the patient from the ground so that the water may run out. With the arms underneath the abdomen lift the patient up quickly two or three times with a jerk. Water from the lungs will thus be forced out. Do not take more than half a minute to do this. Place the patient on the ground face down, and with head turned to one side and resting on an arm. Kneel astride of the patient, and place the palms of your hands across the small of his back, thumbs touching. Allow your weight to fall on your wrists by bending your body slowly forward. Now release the pressure by swinging backward. Continue these motions for four or five

seconds at a time, at about the rate that one breathes. Victims of drowning accidents have been brought back to life after hours of work. If there are other persons to help, have them rub the arms and legs of the patient toward the body, as this helps the circulation. When respiration is restored, cover the patient with warm blankets and place hot-water bags at the hands and feet. After consciousness has returned warm drinks may be given.

What to Do in Case of Suffocation and Electric Shock. In case of suffocation, where the patient has lost consciousness, start artificial respiration, and send for a doctor at once. In case of electric shock a rescue must be effected first. Remember that live wires can transfer electricity through the body of the victim to you. To prevent receiving a shock, it is necessary to stand on dry wood, cloth, or rubber, and remove the wire with a piece of dry wood, or cut it with an ax having a dry wooden handle. If the patient is lying on the wire, place coats under his head and feet and lift him off. As soon as you have rescued the victim start artificial respiration at once, for time is a very important factor, especially if he has become unconscious. Treatment for lightning shock is the same as for electric shock.

What to Do in Case of Sunstroke or Fainting. Sunstroke and heat exhaustion are usually brought about by working in excessive heat, either indoors or out of doors. Too heavy clothing and hats which do not protect the head from the sun's rays help bring on this condition. The results are often very serious, and anyone feeling the effect of the heat either as dizziness and weakness (which are the symptoms of heat exhaustion) or pain in the head and great oppression (the symptoms of sunstroke) should lie down at once. The necessary thing to do is to reduce the body temperature as quickly as possible.

Do this by applying ice to the head and the chest, or by giving the victim a cool bath. In the case of heat exhaustion, such stimulants as tea, coffee, or aromatic spirits of ammonia may be given.

A fainting attack is brought on by a decrease in the amount of blood in the brain. A person feeling dizzy should lie down with the head slightly lower than the rest of the body. Give him plenty of fresh air and loosen his clothing. Respiration may be stimulated by putting cold water upon the face and chest. Aromatic spirits of ammonia may be inhaled.

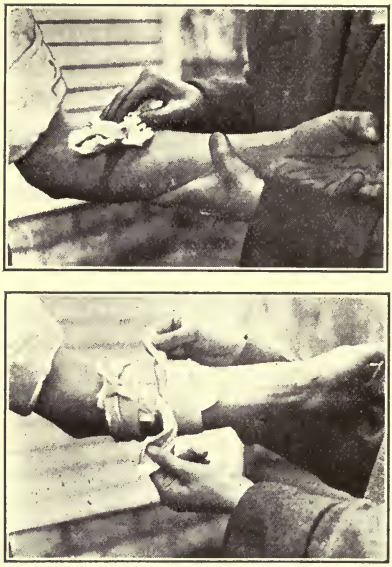
What to Do in Accidents Where Bones Are Broken. In case of broken bones, the first thing to do is to put the patient in as comfortable a position as possible, and then send for a doctor. If some time must elapse before a doctor can treat the fracture, make smooth splints of wood and tie them about the broken bone with strips of any cloth or a necktie. Remember that the broken bones must be held as nearly as possible in a natural position and must not be allowed to move about. Transportation of the patient must be done with the greatest care in order to have no movement of the broken bones.

A temporary bandage for a broken arm. Why must the arm be kept immobile?

Practical Exercise. Make a demonstration before the class of first-aid treatment of a broken leg, broken collar bone, or a dislocated finger.

What to Do to Stop Bleeding. Frequently a person's life may be saved if one knows what to do and can act

quickly. Wounds that bleed steadily, even if they are deep, are not necessarily dangerous and may usually be controlled by placing the wounded person flat on the back and binding a pad or wad of sterile gauze or any clean cloth over the wound. But if the blood comes in spurts and is bright red, an artery has been cut. This means that pressure should be applied between the cut and the heart. You can sometimes do this with your fingers. If the cut is in a limb, a tourniquet (tōōr′nĭ-kĕt), made by knotting a handkerchief and twisting it tightly by means of a stick so the knot presses on the artery, can be used. A physician should be obtained at the earliest possible moment and the patient kept absolutely quiet. Open wounds must be kept clean. If a wound is covered with a bandage or compress of gauze, it is *very* important that such material be absolutely clean. Washing the surface of the wound to get out the dirt is necessary, and if iodine or Mercurochrome is available, pour some over the open surface of the wound. The chief danger from a cut or wound is that germs may get in and start an infection. Therefore, cleanliness is the first need.



What two methods of treating cuts are shown here? Why the difference?

What to Do for Burns. Burns are often very serious because of the difficulty of getting them to heal. Slight burns may be healed by excluding the air with a thin

paste of baking soda and a little water. Put on a light bandage to keep this paste in place. Severe burns require the attention of a physician. A picric acid dressing may be used for immediate relief, after the clothes have been cut away or removed.

How to Treat Poisons. In case of a poisonous snake bite, open the wound at once to induce free bleeding; wash it with potassium permanganate, and give the person strong doses of a stimulant, such as aromatic spirits of ammonia. Antivenin serum should be administered as soon as possible, as the poison works very quickly. Poison ivy is relieved by washing the surface with a solution of potassium permanganate. In all poisons taken into the stomach give an emetic [1] at once. A good plan is to first give raw white of egg in water or milk, followed by warm salt water, mustard water, or anything to get the poison out of the stomach. The emetic will usually be suggested on the label of the bottle containing the poison. Exceptions to the general rule for emetics are that no emetics should be given with strong acids or alkalies. In this case we must apply our knowledge of household chemistry. Acids and bases should be neutralized, using soda or dilute ammonia for acids and vinegar or lemon juice for alkalies.

Home Medicine Chest. A few simple remedies should be kept at home in order to take care of simple ailments. The following supplies are suggested:

Alcohol, 4 ounces
Aromatic spirits of ammonia (rubber cork)
Castor oil, 4 ounces
Limewater, 2 ounces
Witch hazel, 4 ounces
Carbolized vaseline, 1 tube
Soda mint tablets, 100 tablets
Adhesive tape, 1 spool
Antiseptic gauze, 1 package
Absorbent cotton, ½ pound
Gauze bandages, 6 rolls, various widths
First-aid outfits (Red Cross), 2
Iodine and Mercurochrome

[1] **Emetic** (ē-mĕt'ik): inducing to vomit.

SELF-TESTING EXERCISE

Select from the following list those words which best fill the blank spaces in the sentences below and arrange the words in proper numerical order. A word may be used more than once.

less	flat	intersections	between
back	motionless	wrong	drowning
upright	fewer	prone	air
roadside	side	bandage	way
cool	pressure	more	means
hot	beside	stimulants	tourniquet
right	splint	pedestrians	emetic

Motor accidents kill and maim (1)____ children than any other one cause. Most accidents occur at (2)____ of streets. Therefore, we should be alert and be sure we have (3)____ of (4)____ there. Most accidents to (5)____ also occur at intersections. In case of accident we should keep (6)____ and be able to use first aid when it is necessary. In apparent drowning the (7)____ (8)____ method of artificial respiration is best. In case of sunstroke or fainting place the patient (9)____ on the (10)____, give (11)____, as aromatic spirits of ammonia, and plenty of fresh (12)____. In case of a broken bone make a (13)____ so as to keep the bone (14)____ until a doctor comes. In case of a cut artery a (15)____ applied (16)____ the heart and the wound may save a life. In cases of poisons which are not strong acids or alkalies give an (17)____.

PROBLEM TESTS

Test 1. Check the statement or statements which best answer the problem.

You stop at a filling station to get gasoline and leave your engine running. The attendant asks you to turn off the switch. Why does he do this? He does it because:

(1) You are wasting gasoline.

(2) He might be overcome by carbon monoxide while filling the tank.

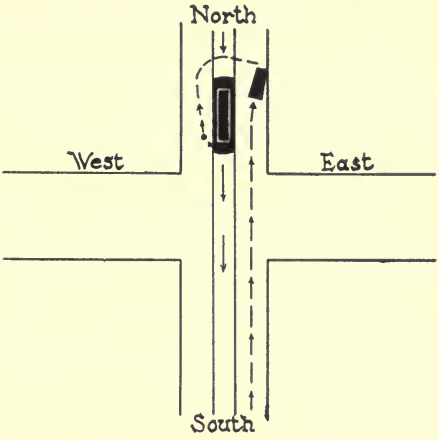
(3) The exhaust might ignite fumes from the open tank of gasoline.

(4) The noise of the engine makes it hard for him to ask you the necessary questions about service.

(5) It is bad for the engine to let it idle.

Test 2. Study the diagram carefully before answering the question.

You get off a street car going south and walk around the back of the car to cross to the east side of the street. As you step out from behind the car, you are knocked down by an auto which is going fifteen miles an hour in a northerly direction. Who is at fault in this accident and why?



THE REVIEW SUMMARY

The generalizations that can be made on this unit are numerous. You may change the list that follows if you so desire, as this is giving you only a partial list of those that you might make for your review summary. Some of the generalizations are:

1. The human body is a self-direction machine which oxidizes fuel to release energy.
2. The nervous system controls the human machine.
3. The skin is a heat-regulating apparatus which also protects the body.
4. Bones act as levers while muscles exert power and give us movement of the body machine.
5. Food must be digested before it can be used by the body.
6. At the present time automobiles are our greatest sources of accidents.

Before making your review summary, test your knowledge of the facts of the unit by checking over the text so as to be sure you know the facts underlying the generalizations. Then, using the generalizations, the material in the text, and everything you have read, seen, or done yourself, make a summary outline for your notebook. This outline you may use when you make a recitation.

TEST ON FUNDAMENTAL CONCEPTS

Make two vertical columns in your workbook. Head one CORRECT *and the other* INCORRECT. *Under the first place the numbers of all statements you believe to be correct. Under the second place all the numbers of the statements you believe to be incorrect. Your grade = right answers* $\times$ 2.

I. **The human machine is like an automobile because:** (1) both use fuel to release energy; (2) both have a protective covering; (3) both possess the same building material; (4) both form wastes that have to be removed; (5) both have a framework.

II. **The human machine is unlike an automobile because:** (6) one is self-directed, the other not; (7) both can be self-repaired; (8) one is a perfect machine, the other is not; (9) one is made entirely of one material, the other is not; (10) one needs air, the other does not.

III. **The skin:** (11) is an organ of heat production; (12) should be powdered frequently so as to keep dirt out of the pores; (13) is a means of individual protection; (14) regulates body temperatures by means of the sweat glands; (15) is a dead covering.

IV. **Bodily movement is accomplished:** (16) by the expansion of blood in the muscles; (17) by the contraction and relaxing of muscles alone; (18) by means of muscles attached to bones which act as levers; (19) better with high-heeled shoes; (20) in part by means of the ligaments and tendons.

V. **The human machine uses food:** (21) to make new parts; (22) to repair old parts; (23) in the stomach; (24) to release energy in the cells; (25) because it tastes good.

VI. **Good health is largely determined by:** (26) a strong constitution; (27) living in the country; (28) getting at least 12 hours sleep every night; (29) getting recreation, work, and rest each day; (30) cheerfulness, optimism, and common sense.

VII. **Digestion is necessary:** (31) in order to make the food taste good; (32) in order to get the food out of the food tube; (33) if the blood is to be supplied with food; (34) in order to get food into the cells; (35) if work is to be done by the body.

VIII. **Your personal habits:** (36) do not ever affect others; (37) may affect others if you are sick; (38) largely determine the state of your own health; (39) should make for clean living and clean thinking; (40) should be centered on making your clothes and person as attractive as possible.

IX. **The human machine:** (41) is controlled by the nervous system; (42) is entirely directed by stimuli from without; (43) is entirely directed by our thoughts; (44) is controlled entirely by endocrine glands; (45) is controlled by all of the above.

X. **Safety education and first aid are important because:** (46) children's deaths from accidents are increasing; (47) you never can tell when an accident will occur; (48) rattlesnakes are numerous in the deserts of the West; (49) over 90,000 people died and 200,000 were injured in accidents last year; (50) over 1 per cent of all boys and girls in school are hurt in accidents every year.

THOUGHT QUESTIONS

1. Constance is fifteen pounds under weight. What should she do to gain her normal weight?
2. Clara weighs ten pounds more than normal and wants to go on a diet. What should she do?
3. George is growing rapidly, has stoop shoulders, and a flat chest. He is more than 10 per cent under weight. He is a good runner and wants to try out for end on the school team. What should he do about it?
4. John is playing guard in basket ball but weighs fifteen pounds less than the coach thinks he should. What should he do to bring up his weight?
5. Should Tom, who is fifteen and growing rapidly, break training after the football season is over? Justify your answer.
6. What can you do to decrease auto accidents?
7. Why must food be digested before it can be used in the body?
8. What would you do if you were alone with a friend who met an accident in which his arm was broken and an artery severed in the same arm near the break?
9. What would you do in case of a fire in the motion picture projector used in the science room?
10. What would you do if you were alone in the laboratory and should be severely burned by acids?

REPORTS UPON OUTSIDE THINGS I HAVE READ, DONE, OR SEEN

1. Report upon an article related to some topic discussed in this unit. The article may be from a current number of a science magazine or from some popular science book you have read.
2. The value of pain.
3. Comparison of skeletons of different kinds of animals.
4. Do animals think?
5. Automobile accidents in my state for the last year and how they might have been lessened in number.
6. Under what conditions might narcotics be useful? If useful, who should use them?

SCIENCE RECREATION

1. Make a series of your own finger prints, right and left hands. Compare them with prints of other members of your class.

2. Find examples of joints in the skeleton. There are three kinds: ball and socket, hinge joints, and sutures, such as are found in the skull.

3. Locate in your own mouth the position and number of each of the following kinds of teeth: incisors, or cutting; canines, or tearing; molars, or grinding.

4. Make a list of the tissues of the body and locate them on a diagram.

5. Learn to use different kinds of bandages, especially the triangular and roller bandages.

6. Keep a monthly record as suggested in the following table to form correct health habits.

Monthly Record	1	2	3	4	5	6	7	8	9	10
1. Age										
2. Weight										
3. Height										
4. Chest measure										
(1) Expanded										
(2) Contracted										
(3) Chest expansion = (1) − (2)										
5. Lung capacity										
6. Time can hold breath										
7. Eye test										
8. Hearing										
9. Grip test										
10. Lifting strength										

SCIENCE CLUB ACTIVITIES

1. Plan a safety first assembly to be given by the club.

2. Organize a safety patrol to control traffic and pedestrians outside the school grounds.

3. Organize a first-aid club.

4. Make a chart for use in the science room, giving a list of all the common poisons and the proper treatment for each.

5. Compare the first aid cabinets in the school with ideal medicine cabinets and make efforts to make them as near perfect as possible.

6. Plan the equipment for an ideal school rest room and start one.

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GLOSSARY

GLOSSARY OF IMPORTANT TERMS

The diacritical marks are those used in the Webster school dictionaries.

Absorbed (ăb-sôrbd′): taken in.
Accommodation (ă-kŏm′ō-dā′shŭn): adapting the lens of the eyes for near and distant vision.
Adaptation (ăd′ăp-tā′shŭn): modification of a plant or animal fitting it more perfectly to live in its environment.
Alkali (ăl′kȧ-lī): a substance having marked basic qualities, including ability to turn red litmus blue.
Ammonium chloride (ă-mō′nĭ-ŭm klō′rīd): a chemical compound.
Amphibian (ăm-fĭb′ĭ-ăn): an animal that spends part of its life in the water and part on land, as frogs and toads.
Aphid (ā′fĭd): a plant louse.
Aquarium (ȧ-kwā′rĭ-ŭm): a glass tank of water.
Archimedes (är′kĭ-mē′dēz): a Greek scientist.
Arcturus (ärk-tū′rŭs): a first-magnitude star.
Artery (är′tĕr-ĭ): one of the large tubes which carry blood from the heart to various parts of the body.
Astigmatism (ȧ-stĭg′mȧ-tĭz′m): a defect of the eye which causes imperfect images.
Astrologer (ăs-trŏl′ō-jĕr): one professing to foretell events by aspects of the stars.
Astronomer (ăs-trŏn′ō-mĕr): one having knowledge of the heavenly bodies.
Atom (ăt′ŭm): the smallest particle of a substance that can exist.
Atomizer (ăt′ŭm-īz′ĕr): an instrument to make a fine spray.

Bacteria (băk-tē′rĭ-ȧ): a certain group of microscopic plants, some of which cause diseases.
Bacteriologist (băk-tē′rĭ-ŏl′ō-jĭst): an expert in the study of bacteria.
Boötes (bō-ō′tēz): the constellation containing Arcturus.
Brontosaurus (brŏn′tō-sô′rŭs): an extinct animal of huge size.
Buoy (boi): to keep from sinking.

Calorie (kăl′ō-rĭ): the amount of heat necessary to warm 1 kilogram of water 1° C. or about 4 pounds of water 1° F.
Calorimeter (kăl′ō-rĭm′ē-tĕr): apparatus for measuring amount of heat in foods.
Calyx (kā′lĭks): the outer floral leaves of a flower. All the sepals taken together.
Capillaries (kăp′ĭ-lā-rĭz): fine, hairlike tubes; the very small blood vessels through which the blood flows from the arteries to the veins.
Carbohydrate (kär′bō-hī′drāt): a group of compounds containing carbon, hydrogen, and oxygen, as sugar and starch.
Carnivorous (kär-nĭv′ō-rŭs): living on flesh.
Cartilage (kär′tĭ-lâj): a translucent elastic tissue.
Cassiopeia (kăs′ĭ-ō-pē′yȧ): name of a constellation.
Celestial (sē-lĕs′chăl): pertaining to the sky or visible heavens.
Cell (sĕl): a small structural unit of which plants and animals are composed.
Cellophane (sĕl′ō-fān): a transparent wrapping "paper" having the composition of rayon.
Centigrade (sĕn′tĭ-grād): name of metric thermometer, on which the distance between the freezing point and boiling is divided into 100 parts or degrees.
Chaparral (chăp′ȧ-răl′): a dense thicket of stiff or thorny shrubs.
Chlorophyll (klō′rō-fĭl): the green coloring matter of plants.
Circulation (sûr′kū-lā′shŭn): the process by which oxygen and blood flow to all parts of the body.
Combustion (kŏm-bŭs′chŭn): act of burning.
Compound: substance formed by the chemical union of elements.
Concave: curving inward like the inside of a ball.

Condensation (kŏn′dĕn-sā′shŭn): changing from gas to liquid.
Condensed (kŏn-dĕnst′): changed from a vapor or gas to a liquid.
Conduction (kŏn-dŭk′shŭn): passing from particle to particle, as heat.
Conifer (kō′nĭ-fẽr): cone-bearing tree.
Constellation (kŏn′stĕ-lā′shŭn): a group of fixed stars.
Convection (kŏn-vĕk′shŭn): transfer of heat by currents in gases or liquids.
Convex (kŏn′vĕks): curving outward; opposite to concave.
Copernicus (kō-pûr′nĭ-kŭs): an astronomer (1473–1543) who first explained that the apparent rotation of the heavens was due to the rotation of the earth.
Corolla (kŏ-rŏl′*ȧ*): the inner petals of a flower.
Corpuscle (kôr′pŭs′l): a minute cell in the blood or lymph.
Cotyledon (kŏt′ĭ-lē′dŭn): the first leaf or pair of leaves developed in seed plants.
Crustacean (krŭs-tā′shăn): segmented animal with jointed legs and a crustlike shell.
Cylinder (sĭl′ĭn-dẽr): the chamber in an engine in which the piston moves.

Daguerreotype (d*ȧ*-gĕr′ō-tīp): an early variety of photograph.
Deciduous (dẽ-sĭd′ū-ŭs): shedding leaves in winter.
Diaphragm (dī′*ȧ*-frăm): a vibrating disk or membrane as in the telephone. Muscular partition separating the chest cavity from the abdomen.
Diffused (dĭ-fūzd′): spread.
Diffusion (dĭ-fū′zhŭn): the mixing of the particles of two substances in solution.
Digest (dī-jĕst′): to change food into a form that the blood can absorb.
Diphtheria (dĭf-thẽ′rĭ-*ȧ*): an infectious disease of the throat.
Disinfect (dĭs′ĭn-fĕkt′): to purify by killing the germs of disease.
Distillation (dĭs′tĭ-lā′shŭn): act of driving off gas from liquids and then condensing the gas by cooling.
Dormant (dôr′mănt): inactive.

Electrolysis (ē-lĕk-trŏl′ĭ-sĭs): the separation of a compound into its parts by means of an electric current.
Electron (ẽ-lĕk′trŏn): that part of an atom that carries a negative charge of electricity.
Element (ĕl′ẽ-mĕnt): a substance that cannot be broken up into simpler substances.
Embryo (ĕm′brĭ-ō): an organism in early stages of development.
Emulsion (ẽ-mŭl′shŭn): a liquid preparation in which minute particles remain in suspension.
Endocrine (ĕn′dō-krĭn): organs which secrete fluids.
Energy (ĕn′ẽr-jĭ): the capacity to do work.
Environment (ĕn-vī′rŭn-mĕnt): surrounding conditions or influences.
Enzyme (ĕn′zīm): a substance which effects certain chemical changes.
Epidermis (ĕp′ĭ-dûr′mĭs): outer layer of the skin.
Eradicate (ẽ-răd′ĭ-kāt′): to destroy utterly.
Erosion (ẽ-rō′zhŭn): the process by which rocks and soil are scoured off and carried away by water.
Evaporation (ẽ-văp′ō-rā′shŭn): act of changing a solid or a liquid to a vapor.
Exhale (ĕks-hāl′): to breathe out.
Exhilaration (ĕg-zĭl′*ȧ*-rā′shŭn): act of being enlivened or made glad.
Expiration (ĕks′pĭ-rā′shŭn): passing air out of the lungs.
Explosion (ĕks-plō′zhŭn): a sudden bursting from great pressure.

Factor (făk′tẽr): one of the parts of a product.
Fahrenheit (fă′rĕn-hīt): a thermometer in which the freezing point of water is 32° and the boiling point is 212°.
Fatigue (f*ȧ*-tēg′): exhaustion of strength.
Fermentation (fûr-mĕn-tā′shŭn): the production of alcohol and carbon dioxide by the action of yeast.
Fertilization (fûr′tĭ-lĭ-zā′shŭn): the union of a male germ cell with the female germ cell or egg.

Fluctuation (flŭk′tū-ā′shŭn): varying or changing in strength of current.
Focus (fō′kŭs): a point at which rays as of light, heat, sound, etc., meet, after being reflected or refracted.
Fossil (fŏs′ĭl): remains or impressions of a living thing preserved in rock of ancient date.
Friction (frĭk′shŭn): act of rubbing one thing against another.

Geologist (jē-ŏl′ō-jĭst): a geological student or investigator.
Germ (jûrm): a small plant or animal that may produce disease.
Germinate (jûr′mĭ-nāt): to begin to grow, to sprout.
Geyser (gī′sēr): a spring which throws intermittent jets of hot water.
Glacier (glā′shēr): a slowly moving body or field of ice.
Gland: an organ of the body which makes and gives off a fluid.
Gravity (grăv′ĭ-tĭ): the pull of the earth upon objects.
Gyrocompass (jī′rō-kŭm′pȧs): a non-magnetic compass.

Hazards (hăz′ȧrds): dangers.
Herbivorous (hēr-bĭv′ō-rŭs): living on plants.
Huygens (hī′gĕnz): a Dutch astronomer (1629–1695).
Hyacinth (hī′ȧ-sĭnth): a garden plant.
Hydra (hī′drȧ): a small fresh-water animal.
Hygiene (hī′jĭ-ēn): a study of the proper care of the body.
Hyposulphite of soda (hī′pō-sŭl′fīt): a chemical used in photography.

Igneous (ĭg′nē-ŭs): rocks which have been melted by intense heat, that is, by volcanic action.
Immune (ĭ-mūn′): free from or protected against any particular disease.
Incident (ĭn′sĭ-dĕnt): falling upon a surface.
Infectious (ĭn-fĕk′shŭs): catching; communicable; a germ disease.
Inhale (ĭn-hāl′): to breathe in.
Inspiration (ĭn′spĭ-rā′shŭn): the act of breathing in.
Insulate (ĭn′sū-lāt): to separate one body from another by a material that does not allow heat or electricity to pass through it.
Insulator (ĭn′sū-lā′tēr): a body through which an electric current passes only slightly or not at all.

Jonquil (jŏn′kwĭl): a garden plant.

Kaleidoscope (kȧ-lī′dō-skōp): a device to show symmetrical designs by use of two mirrors.

Larva (lär′vȧ): the immature worm-like stage of insect development.
Lava (lä′vȧ): fluid rock from a volcano or such rock hardened.
Legume (lĕg′ūm): a plant, such as the pea or bean, bearing pods.
Lever (lē′vēr): a bar capable of turning about one point.
Ligament (lĭg′ȧ-mĕnt): a tough band of tissue.
Luminous (lū′mĭ-nŭs): giving out light.

Magnesium (măg-nē′zhĭ-ŭm): a silver-white metal.
Magnet (măg′nĕt): a piece of iron or steel which attracts iron or steel.
Magnetism (măg′nĕt-ĭz′m): having the property of being magnetic, of having attraction.
Mammal (măm′ăl): all animals that nourish their young with milk.
Matter: anything that occupies space and has weight.
Membrane (mĕm′brān): a thin pliable animal or vegetable tissue.
Metamorphic rock (mĕt′ȧ-môr′fĭk): rock changed by heat, pressure, or movement.
Micro-organism (mī′krō-ôr′găn-ĭz′m): any organism of microscopic size.
Molecule (mŏl′ē-kūl): smallest part of a substance that can exist alone.
Mollusk (mŏl′ŭsk): an unsegmented soft-bodied animal, sometimes bearing a shell.
Mulch (mŭlch): a loose covering.
Muscle (mŭs″l): a mass of tissue whose function is the production of motion.

Myriad (mĭr′ĭ-ăd): an indefinite large number.

Narcotic (när-kŏt′ĭk): a drug which in great doses produces stupor.
Neutralize (nū′trăl-īz): to counteract.
Nucleus (nū′klē-ŭs): a central mass.
Nutrient (nū′trĭ-ĕnt): substances which furnish food to the body.

Opaque (ō-pāk′): not permitting light to pass through.
Organic (ôr-găn′ĭk): pertaining to living plants and animals.
Oxidation (ŏk′sĭ-dā′shŭn): act of combining with oxygen.
Oxidize (ŏk′sĭ-dīz): to add oxygen.

Parallel (păr′ă-lĕl): lying evenly everywhere in the same direction.
Pasteurization (păs′tẽr-ĭ-zā′shŭn): a process for checking growth of bacteria in fluids by heating.
Perpendicular (pûr′pĕn-dĭk′û-lȧr): in the line of gravity or at right angles to a surface.
Perspiration (pûr′spĭ-rā′shŭn): fluid excreted by sweat glands.
Phenomenon (fē-nŏm′ē-nŏn) (*pl.* phenomena): a happening or event.
Phosphorus (fŏs′fŏr-ŭs): a chemical element which burns at a low temperature.
Physiology (fĭz′ĭ-ŏl′ŏ-jĭ): the study of the structures of the body and how they work.
Piccard (pē′kȧr′): Belgian scientist who made the first trip into the stratosphere in a closed gondola.
Pistil (pĭs′tĭl): the central structure of a flower, which contains the ovary.
Pituitary (pĭ-tū′ĭ-tă-rĭ): a ductless gland.
Pneumonia (nû-mō′nĭ-ȧ): a disease characterized by inflammation of the lungs.
Pollen (pŏl′ĕn): fine dust grains from the anthers of flowers.
Pollination (pŏl′ĭ-nā′shŭn): the transfer of pollen of one flower to the stigma of another.
Prism (prĭz′m): a body with similar ends and rectangular faces.
Propaganda (prŏp′ȧ-găn′dȧ): an organization for spreading a particular system of principles.
Protein (prō′tē-ĭn): food material containing carbon, hydrogen, oxygen, and nitrogen. Foods containing proteins are meat and eggs.
Proton (prō′tŏn): the part (nucleus) of the atom that has a positive electric charge.

Quantum (kwŏn′tŭm): a certain quantity.

Radiant (rā′dĭ-ănt): given out or emitted by rays.
Radiation (rā′dĭ-ā′shŭn): the transfer of energy across space, as heat and light from the sun.
Reflection (rē-flĕk′shŭn): turning or bending back.
Refraction (rē-frăk′shŭn): bending of a ray going obliquely from one medium into another in which the velocity is different.
Refrigeration (rē-frĭj′ēr-ā′shŭn): a process of cooling.
Refrigerator (rē-frĭj′ēr-ā-tēr): a box or room for keeping things cool.
Respiration (rĕs′pĭ-rā′shŭn): act of breathing.
Retina (rĕt′ĭ-nȧ): the membrane of the eye which receives the image.
Rigel (rī′jĕl): a first magnitude star in the constellation Orion.
Rotate (rō′tāt): to turn.

Secretion (sẽ-krē′shŭn): material separated and discharged by cells.
Sedimentary rocks (sĕd′ĭ-mĕn′tȧ-rĭ): rocks formed from deposits made under water.
Soluble (sŏl′û-b′l): to dissolve.
Solution (sŏ-lū′shŭn): a liquid in which a solid or a gas has dissolved.
Solvent (sŏl′vĕnt): having power of dissolving.
Spectroscope (spĕk′trŏ-skōp): an instrument for forming spectra.
Sperm (spûrm): male reproductive cell.
Spherical (sfĕr′ĭ-kăl): globular in form.
Stalactite (stȧ-lăk′tīt): a formation of calcium carbonate, resembling an icicle.

Stamen (stā′mĕn): the part of a flower which contains the pollen.
Sterilized (stĕr′ĭ-līzd): freed from disease bacteria.
Stimulus (stĭm′ū-lŭs): an agent capable of producing an impression on a sensory organ.
Stoma (stō′mȧ) (*pl.* stō′mȧ-tȧ): mouthlike opening in epidermis of green leaf.
Stratified (străt′ĭ-fīd): arranged in layers.
Sulphuric (sŭl-fū′rĭk): acid composed of hydrogen, sulphur, and oxygen.

Torricelli (tŏr′rē-chĕl′lē): an Italian physicist who devised the method of measuring atmospheric pressure in 1643.
Tourniquet (to͝or′nĭ-kĕt): a device for arresting bleeding.
Translucent (trănz-lū′sĕnt): allowing some light to pass through, but not enough to permit objects to be clearly seen through the substance.
Transmit (trănz-mĭt′): to pass on.
Transparent (trănz-pâr′ĕnt): allows light to pass through easily.
Tuberculosis (tū-bûr′kū-lō′sĭs): an infectious disease of the lungs.

Vacuum (văk′ū-ŭm): a space from which all air or other matter is removed.
Vaporization (vā′pēr-ī-zā′shŭn): act of changing from liquid to a gas.
Vaporize (vā′pēr-īz): to change to a vapor.
Vegetation (vĕj′ē-tā′shŭn): any sort of plant life.
Veins (vānz): tubes carrying blood back to the heart.
Vitamin (vī′tȧ-mĭn): regulative food substance necessary to life.

Weathering (wĕth′ĕr-ing): the process of breaking up and changing rock to soil.

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